TONY BLAIR INSTITUTE FOR GLOBAL CHANGE

Pandemic-Proofing Travel

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Foreword by Andrew Adonis

This is the most considered analysis and set of recommendations I have seen on how to progressively reopen public transport systems in the face of the continuing Covid-19 pandemic. It is an important guide for the government and for local and national policymakers.

It makes clear that public transport systems without substantial fresh air or advanced air-filtration systems are the greatest challenge and risk in terms of contagion. It recommends a twin-track strategy of social distancing to the extent possible, combined with a radically enhanced approach to cleaning, hand sanitation, mask-wearing and the control of passageways and entrances and exits to buses, trains, stations and airports to manage passenger flows with minimum contact between passengers. All this requires serious organisation, service by service and location by location.

These measures are important in their own right. But as the paper argues, competent demonstration that this new approach is taking place, with a full demonstration of this "new normal" to and through the media, is vital to building the confidence necessary for the public to start using public transport again in large numbers.

There may be scope, over time, for more radical technological approaches to air filtration on trains and buses, as already exists on most planes. But it will not come immediately, and the measures in this paper are vital immediate steps to enable public transport to return to use in the weeks and months ahead.

Andrew Adonis
Former UK Secretary of State for Transport

Overview

A critical aspect of exiting lockdown is how we get the economy moving again. This is true at both a domestic and international level.

Nationally, we rely on our major cities to drive the economy. Public transport plays a key role as part of that economic infrastructure. In London, 36 per cent of trips in 2018 were by public transport.[1]

To restart the economy in major cities like London we need to get people moving again.

As with many areas of responding to Covid-19, the goal is mitigating risk. Moving people around on public transport with no risk is impossible.

Covid-19 is transmitted through the emission of viral droplets by an infected person when they cough or sneeze, or via aerosol droplets from speaking and breathing. This risk is heightened in confined indoor spaces.

A meeting of the Scientific Advisory Group for Emergencies (SAGE) in May made clear that: "There is a good body of evidence to associate public transport with transmission of respiratory infections from a mixture of epidemiological studies and modelling studies. While some studies show no association between public transport and risk, the overall weight of evidence is towards an increased risk of infection among public transport users."[2]

At an international level, aviation is a vital means of transport for both people and cargo, and how it revives will be important in wider global economic trends. 4.4 billion passengers flew in 2018.[3]

As with domestic travel, moving millions of people around the world without any infection risk is prohibitively difficult. So, again, the aim is making this form of transport as safe as possible.

This paper seeks to set out the challenges in how we get our transport systems moving again, while living alongside the virus, and surfaces ideas for discussion on potential ways we can move forward.

For domestic transport we recommend the use of face masks and underline the importance of social distancing, which, critically, will require a significant reduction in demand on services.

Rail companies have suggested that passenger capacity on trains may need to be reduced by 70 to 90 per cent if 2-metre social distancing is enforced. Transport for London (TfL) has said passenger capacity on tubes

1 http://content.tfl.gov.uk/travel-in-london-report-12.pdf

and buses may only be 13 to 15 per cent of normal levels for the same reason.[4]

Most businesses will therefore need to take a pragmatic stance on their employees ideally working from home for the medium term, or at least working to very flexible hours.

We believe it is important that companies think imaginatively in terms of future working arrangements, making preparations now, where possible and effective, to fully embrace new ways of working. A number of companies have shifted to working largely from home, and we support such moves where it is feasible.

For international travel we recommend the mandatory use of masks, with rapid testing and mobility credentials that sit atop a secure and user-centric digital identity infrastructure made available to allow people to prove they are safe to travel.

2 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888755/4b._EMG-Transport_Overview_18502020-updated_S0407.pdf

3 https://www.airportwatch.org.uk/2019/08/4-4-billion-air-trips-taken-world-wide-in-2018-number-was-2-63-billion-in-2010/

4 https://www.ifs.org.uk/publications/14844

Importance of Transport

Global travel and tourism accounts for 10.3 per cent of global GDP, contributing almost $9 trillion to the global economy. The sector accounted for one in ten jobs in 2019.[5]

Estimates on the impact of Covid-19 on global transport and tourism indicate a potential loss of 100 million jobs and $2.7 trillion.

Table 1 – Potential impact of Covid-19 on travel and tourism

	Potential total job losses (millions)	**Total GDP loss (US$ billion)**
Asia	−63.4	−1,041.0
Europe	−13.0	−708.5
Africa	−7.6	−52.8
Americas	−14.1	−790.9
North America	−8.2	−680.7
Latin America	−4.7	−83.8
Caribbean	−1.2	−26.4
Middle East	−2.6	−96.2
World	**−100.8**	**−2,689.4**

US$ billion figures are based on 2019 prices and exchange rates

Source: World Travel and Tourism Council[6]

5 https://wttc.org/Research/Economic-Impact

6 *https://wttc.org/News-Article/WTTC-now-estimates-over-100-million-jobs-losses-in-the-Travel-&-Tourism-sector-and-alerts-G20-countries-to-the-scale-of-the-crisis*

The Challenge of Covid-19 for Travel

The coronavirus is spread by respiratory droplets emitted by an infected person when they cough or sneeze. The spread of these droplets is more likely within 2 metres.[7] The virus can also be transmitted through the spread of aerosol particles emitted when an infected person speaks or breathes. These infectious particles can float in the air for up to three hours.[8]

Scientists have been clear that the virus is more likely to spread indoors. Outdoors, in fresh air, with correct social distancing protocols, infection is less likely.

Dr Chris Smith, clinical lecturer in virology at Cambridge University, has said that the chances of outdoor transmission were "vanishingly small" since "the amount of dilution from fresh air is so high".

Dr Muge Cevik, clinical fellow in infectious diseases and medical virology at St Andrews University, analysed different data sets and found that, "transmission risk is higher in close contact and in crowded indoor environments".[9]

A study titled "Indoor Transmission of SARS-CoV-2",[10] published in April, looks at case reports from local Municipal Health Commissions of 320 prefectural cities (municipalities) in China, not including Hubei province, between 4 January and 11 February 2020.

The study identified all outbreaks involving three or more cases and reviewed the major characteristics of the enclosed spaces in which the outbreaks were reported and associated indoor environmental issues.

It found that "all identified outbreaks of three or more cases occurred in an indoor environment, which confirms that sharing indoor space is a major SARS-CoV-2 infection risk."[11]

For all these reasons, the virus poses a big challenge to safely moving large numbers of people via public transport, domestically and internationally.

7 https://www.cdc.gov/coronavirus/2019-ncov/faq.html

8 https://www.health.harvard.edu/diseases-and-conditions/covid-19-basics

9 https://inews.co.uk/news/coronavirus-catch-outside-indoors-why-get-covid-19-explained-426628

10 Indoor transmission of SARS-CoV-2, medRxiv 2020.04.04.2005305, Hua Qian, Te Miao, Li LIU, Xiaohong Zheng, Danting Luo, Yuguo Li

11 https://www.medrxiv.org/content/10.1101/2020.04.04.20053058v1.full.pdf

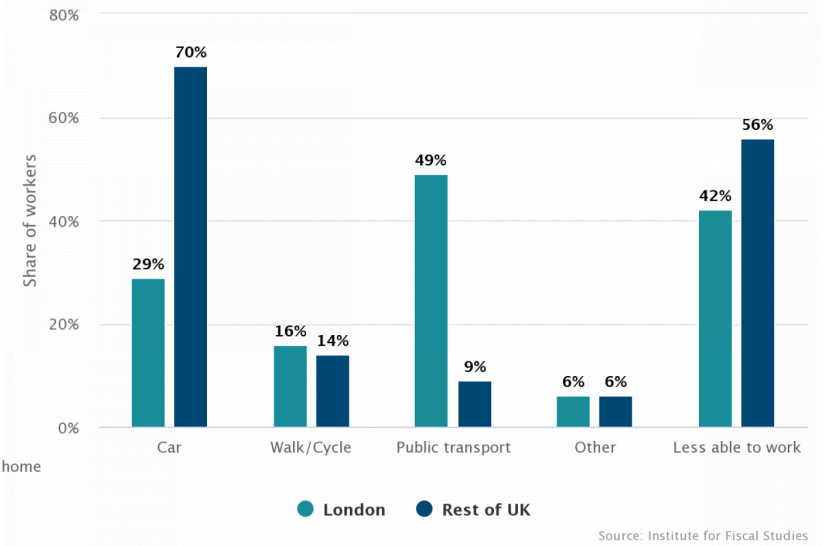
Domestic Travel

As we set out above, public transport plays a vital role in the national economy.

Overall, almost 14 per cent of the UK workforce (4.5 million workers) use public transport.[12]

This is particularly true in the capital, where 49 per cent of workers living in London use public transport.

Figure 1 – Method of travelling to work and ability to work from home



Tubes

Of all the methods of public transport under discussion, tube transport presents the biggest difficultly in terms of mitigating the potential spread of Covid-19. By confining large groups of people in a contained environment, with poor ventilation, there is a significant risk of transmission of the virus.

12 https://www.ifs.org.uk/uploads/Final-BN287-Changes-down-the-line-Flattening-the-curve-of-public-transport-use.pdf

Risk of infection

Research has previously suggested a link between commuting on the London Underground and catching respiratory illnesses.

Dr Lara Gosce of the Institute of Global Health published research in 2018 that showed people who used the Underground were more likely to suffer flu-like symptoms.[13]

It set out the following: "Comparing our results with influenza-like illnesses (ILI) data collected by Public Health England (PHE) in London boroughs, shows a correlation between the use of public transport and the spread of ILI. Specifically, we show that passengers departing from boroughs with higher ILI rates have higher number of contacts when travelling on the Underground. Moreover, by comparing our results with other demographic key factors, we are able to discuss the role that the Underground plays in the spread of airborne infections in the English capital."[14]

Dr Gosce has said recently that the research showed that, "boroughs served by fewer lines – where inhabitants are forced to change line one or more times when travelling on the Underground – have higher rates of influenza-like diseases, compared to well-served boroughs where passengers reach their destination by one direct trip … If you're travelling on a relatively empty train or bus, though, your risks would be different. How long you spend on transport will also play a role – spending more time in contact, and coming into contact with more people will increase your risk … limiting the number of close contacts with potentially infected individuals and objects is important".[15]

Spread of Covid-19

Research has also more specifically looked at the risk of Covid-19 spreading on underground transport.

A study in the US looked at Smartcard data for the Metro in Washington, DC. It estimated that with passenger levels at their pre-Covid levels, three Covid-19 infected passengers would lead to 55 per cent of passengers being infected within 20 days.[16]

Dr Julian Tang, professor at Leicester University's Department of Respiratory Sciences, has said that, "…the packed subways of Tokyo, London and New York are in the worst possible situation for both aerosol

and close contact transmission … The London Underground is old, the trains are very narrow and the carriages are closed at each end so that you can't walk through. That reduces the volume [of air in the space] in there that can reduce the concentration of airborne contaminants."[17]

Dr Tang underlined, however, that the key risk is being in close proximity with others, a risk he notes no ventilation system can fully mitigate.

How to mitigate the risk

For underground public transport, the best ways to mitigate risk are the following:

- **The mandatory use of masks.** This needs to be properly enforced, with passengers only able to travel with masks.
- **Additional face shields for TfL staff.** As we set out in a recent paper on face shields, they provide a high level of protection for the wearer. Given they cover the whole face – the mouth, nose and eyes – a high percentage of viral particles are prevented from reaching the wearer. For this reason we recommended their use for those coming into regular close contact with the public.
- **Regular hand sanitisation.** Hand sanitiser should be made as widely available as possible across the public transport network.
- **Enhanced cleaning.** SAGE has highlighted the importance of sanitisation and cleaning: "The evidence to date indicates with high confidence that SARS-CoV-2 is highly likely to survive for several hours, and probably several days on typical surfaces within public transport. Cleaning of surfaces, particularly those that are frequently

13 https://ehjournal.biomedcentral.com/articles/10.1186/s12940-018-0427-5
14 https://ehjournal.biomedcentral.com/articles/10.1186/s12940-018-0427-5
15 https://www.bbc.co.uk/news/health-51736185
16 https://airqualitynews.com/2020/05/29/coronavirus-recovery-public-transport-is-key-to-avoid-repeating-old-and-unsustainable-mistakes/

touched is likely to be a very important mechanism for reducing transmission. Continuing to promote good hand hygiene and providing additional facilities to enable people to clean their hands more frequently are also important actions."[18]

These enhanced cleaning regimes must be made fully transparent and be well-advertised, so passengers have confidence to travel. The International Association of Public Transport notes a range of examples of how transport providers are communicating with passengers. In Japan, for instance, posters and displays are being used to encourage good hygiene practices in four languages. Such techniques should be embraced and broadened to include public awareness of cleaning procedures that have been put in place.[19]

- **Social distancing.** It is important that efforts are made to ensure a level of social distancing is maintained on the Tube network. In the picture below, we show how the Moscow Metro has sought to space passengers.

17 https://www.bloomberg.com/news/articles/2020-05-27/trains-planes-and-buses-how-to-avoid-coronavirus

18 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888755/4b._EMG-Transport_Overview_18502020-updated_S0407.pdf

19 https://www.lek.com/sites/default/files/insights/pdf-attachments/Public-Transport-Authorities-COVID-19.pdf

- **Reducing demand on services.** This means working with industry and local government to manage office start times, effectively reducing the impact of, or even removing, London's rush hour. Combined with more working from home, this would ultimately mean fewer total journeys that are more evenly spread across a working day.

- **Explore enhanced air filtration on Tube carriages.** Moscow Metro trains have air filters, which are now being changed twice as often as a way to help tackle the virus.[20]

Buses

Bus travel also carries a potential risk of transmission of the virus, and a disproportionate number of bus drivers in London have died due to the pandemic.[21]

There have been fewer studies on the potential risk of viral spread on buses than on the risk of underground travel.

The Telegraph set out some existing evidence on this issue:

- A 2011 *BMC Infectious Diseases* study found that bus and tram travel were linked to an almost six-fold increase in risk of developing influenza-like infections during the flu season.
- A 2011 study in Houston, published in the *Tuberculosis Journal*, found the incidence of tuberculosis was almost eight times higher among commuters spending more than an hour a day on buses: The "regression analysis predicts that for every 1% increase in the proportion of persons whose commute into work on a public bus is 30-44 min the corresponding increase in incidence holding all other variables constant is 0.11; for a commute >60 min the increase in TB incidence is 0.79 or 8 times the baseline".[22]

On buses there is often the option to open windows to improve air circulation, but masks and social distancing will still be essential. Where

windows are not already fitted, we recommend they are retrofitted, as was quickly done with the Routemaster buses in 2015 and 2016. (In September 2015, TfL announced that windows would be installed on the upper deck of all of the then-operational 550 new Routemaster buses, at a cost of £2 million. It was also announced that a further 250 buses on order would have windows fitted. The work was completed by the end of the following summer.

How to mitigate the risk

- **Ensure mandatory wearing of face masks on buses.** Those not wearing masks should be refused travel.

- **Equip bus drivers and other staff on buses with face shields**.[23]
- **Carry out enhanced cleaning regimes on buses.** In most cities in China, for example, the bus fleet is sanitised after each journey, with particular focus on high-risk areas like seats, armrests and handles. At the depots and interchanges, cleaning is done as frequently as every two hours. Cleaning of air-conditioning filters has also been enhanced.[24] In Shanghai ultraviolet light is being used to clean buses (see picture below), as UV radiation can eliminate the virus.

  A briefing by the International Association of Public Transport brings out further areas of best practice in cleaning:

  1. The transport authority for Paris (RATP) has deployed staff to disinfect high-risk touch points.
  2. In Italy, the Azienda Transport Verone (ATV) is using germicidal chlorine-based products to clean surfaces and high-risk areas. The bus fleet underwent a special environmental sanitisation procedure that uses dry steam at 180 degrees Celsius. The entire fleet also

20 https://www.railwaygazette.com/metros/moscow-metro-fights-the-coronavirus/56567.article

21 https://www.wsws.org/en/articles/2020/05/13/lond-m13.html

22 https://pubmed.ncbi.nlm.nih.gov/22094150/

23 https://www.gettyimages.co.uk/detail/news-photo/transport-for-london-london-

underwent an ozone clean, similar to that used in ambulances.

3. Germany's Deutsche Bahn (DB) has increased the use of both soap and disinfectants on trains by up to 20 per cent.
4. South Australia's public transport system had been disinfected daily since early March.[25]

As with our recommendations on cleaning of underground transport, these enhanced cleaning regimes should be made fully transparent so that passengers know what procedures are in place to ensure their safety.

- **Reduce demand and passenger numbers.** This will be achieved through increased working from home and a reduction in the number of journeys taken during rush hour.
- **Explore fitting windows on all buses to help with circulation.** As detailed above, windows were retrofitted on London's new Routemaster buses in 2015, and China has been doing the same during Covid-19 for its air-conditioned buses.[26]

Trains

bus-driver-wearing-a-face-mask-news-photo/1209294849?adppopup=true

24 https://theconversation.com/to-limit-coronavirus-risks-on-public-transport-heres-what-we-can-learn-from-efforts-overseas-133764

25 https://www.lek.com/sites/default/files/insights/pdf-attachments/Public-Transport-Authorities-COVID-19.pdf

26 https://theconversation.com/to-limit-coronavirus-risks-on-public-transport-heres-

As with buses and underground transport, overground train travel also carries significant risk of Covid-19 transmission. This risk, as with other forms of transport, can be mitigated but not removed.

Like bus transport, on trains there is often the possibility of opening windows, which will assist with air circulation. Key elements in determining the risk on train transport will be passenger numbers, how easy it is to maintain social distancing, how often the train stops (and thus how often its doors open and allow fresh air in), and how long someone is on a particular journey.

A 2007 study by Hiroyuki Furuya titled "Risk of Transmission of Airborne Infection During Train Commute Based on Mathematical Model" confirms that the length of journey and the number of passengers are both critical in determining risk.

The study used the Wells-Riley model to quantify the risk of inhalation of airborne infectious particles on commuter trains in Japan, and it focused on the reproduction number for the influenza infection (RA).

The study found the estimated median probability distribution of RA was 2.22. The study noted that if the exposure time is less than 30 minutes, the risk may be low. The exposure time can increase the risk linearly. The number of passengers also increases the risk.[27]

How to mitigate the risk

Key elements in making train travel safer are:

- **Compulsory use of face masks**
- **Face shields for rail transport staff**
- **Availability of hand sanitiser**
- **Enhanced cleaning regimes**
- **Investigation of possible ways to improve ventilation on trains:** This step was also recommended in the 2007 study by Hiroyuki Furuya.
- **Social distancing:** This necessitates reducing demand on services.
- **Increased frequency and capacity of trains**
- **Increased use of e-tickets**
- **Making seat reservations mandatory on all long- distance journeys**
- **Considering retrofitting trains with HEPA filters:** See below in the

what-we-can-learn-from-efforts-overseas-133764

section on International Travel for more detail on how HEPA filters work.

27 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2723643/

New Normal

As the above sections have highlighted, we will need to create a new type of normal for domestic public transport. This will of course involve the compulsory use of masks, enhanced cleaning protocols and access to sanitisation.

The critical element, however, is reducing demand. In our view this requires a medium- to long-term change in the way many of us work.

Working from home, to a large extent, will need to be the new norm. Many companies have found this way of working as effective – if not more effective – than traditional office-based working and have moved to permanent working-from-home protocols. Such steps are to be encouraged, particularly in the coming months, as reducing demand on public transport remains so critical.

A report seen by the BBC indicates that if 2-metre social distancing were maintained on London Underground, only 50,000 passengers would be able to board every 15 minutes, compared with 325,000 every 15 minutes at pre-crisis rush-hour levels.[28] Even with 1-metre social distancing, the capacity only increases to 80,000 every 15 minutes, or just 25 per cent of pre-crisis rush-hour levels.

Reducing demand on services will also require government and transport authorities working very closely with businesses to help manage pressure on services. This will involve, for instance, staggering work hours with almost military precision, and ensuring business and retail work together to look at what hours they can adopt that complement, rather than align directly with, each other.

Reducing demand will also need to go hand in hand with long-term redesign of our modes of transport, affording passengers safer journey experiences.

28 https://www.bbc.co.uk/news/explainers-52534135

International Travel

As set out above, international travel is a critical element of the international economy.

Global travel and tourism accounts for 10 per cent of global GDP. One in four jobs created last year were in this sector.

Estimates on the impact of Covid-19 on global transport and tourism indicate the potential loss of 100 million jobs and $2.7 trillion.

Air travel has expanded dramatically in recent decades, with 4.4 billion passengers carried in 2018.

Compared with domestic travel there are aspects of international travel that make mitigation steps somewhat easier. Principally, airplanes have highly effective air-filtration systems – HEPA filters – that filter the air every couple of minutes and remove almost 100 per cent of bacterial and viral particles. Coupled with enhanced personal sanitisation, plane cleaning and compulsory masks, air travel is, in principle, less risky than being on the London Underground.

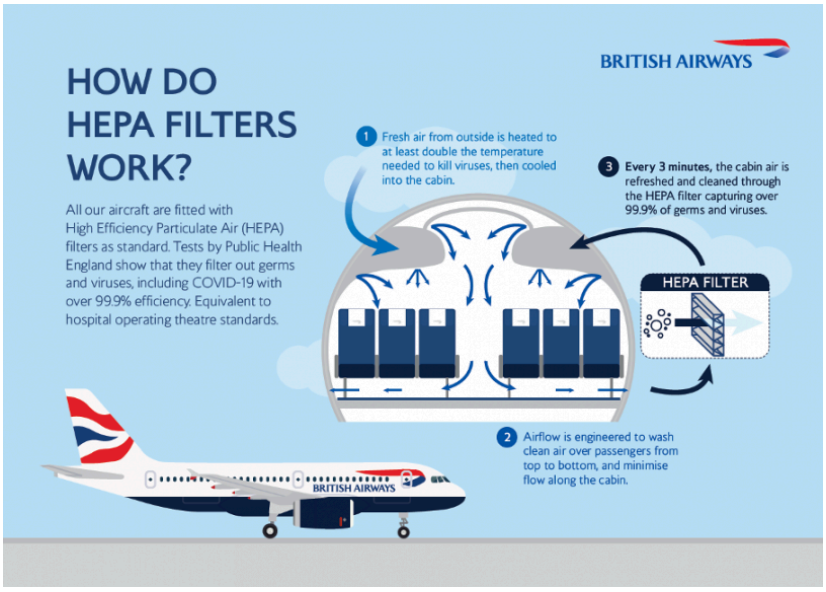
HEPA filters

Most modern airliners are equipped with HEPA (or, High Efficiency Particulate Air) filters.

HEPA filters continually clean the onboard air in the plane and replace it roughly every three minutes.

The trade association Airlines for Europe argues that because of these filters, "...the air in the cabin is comparable with the sterile environment of a hospital operating theatre. Research by leading national and European research institutes as well as the International Air Transport Association confirms that there is little evidence supporting passenger-to-passenger transmission of the Covid-19 virus onboard an aircraft – even without additional protective measures in place."[29]

Figure 2 – An infographic from British Airways explaining how HEPA filters work on planes



Airbus's chief engineer Jean-Brice Dumont argues that given these filters, aircrafts have very clear air: "Every two to three minutes, mathematically, all the air is renewed," he says. "That means 20 to 30 times per hour, the air around you is completely renewed … HEPA filters have standards, and the standards we use in commercial aviation are among the highest standards. They filter out 99.97% of particulates (small particles) of the size of Covid-19."

As Dumont further explains: "The air flows vertically. It is blown from above your head and evacuated from beneath your feet. That makes the level of propagation of anything in the air quite limited. So a passenger from row one, for example, cannot contaminate someone in row 20."[30]

Dr Julian Tang, consultant virologist at the Leicester Royal Infirmary, notes however that these filters do not fully mitigate the risk of Covid-19 transmission: "The problem is that if you're sitting next to somebody – 0.6 metres in economy, say – who's coughing and sneezing in that immediate area, that aerosol will reach you before it has time to reach the filtration system, get filtered and come back down again."[31]

Use of HEPA filters on trains and buses

Because Covid-19 is mainly transmitted through person-to-person contact, it makes sense that prevention measures in small, contained spaces – including trains and buses – focus on the individuals using

29 https://a4e.eu/publications/a4e-reconnect-strategy/
30 https://www.bbc.co.uk/news/business-52822913

these spaces and the surfaces they touch. This is why masks and cleaning are of such importance. However, there is also an opportunity to explore the use of HEPA filtration for these modes of transport. This well-established filtration system effectively captures droplets of the size that cause Covid-19. The virus that causes Covid-19 is approximately 0.125 micron (125 nanometres) in diameter. It falls squarely within the particle-size range that HEPA filters capture with extraordinary efficiency: 0.01 micron (10 nanometres) and above.[32]

While these air-purification systems are almost ubiquitous in commercial planes, their use on other modes of transport is less common.[33] In 2011, Chicago's Metra commuter rail system was outfitted with IQAir HyperHEPA filters, which offered protection against rising levels of carbon in the train carriages. This outfitting took place over a period of just 90 days and saw 839 separate carriages upgraded.[34] The suggestion of using HEPA filters on all modes of transport isn't a novel idea either. The July 1973 edition of *Air Pollution Abstracts* from the US government stated that "the HEPA filtration of all recirculated air is the epidemiological key to halting aerosol transmission of viral induced infection … among human hosts sharing a closed environment. The use of HEPA filters in buses, trains, airplanes and automobiles is suggested."[35]

Given the wide availability of HEPA air-purifying technology, we recommend its use in all modes of transport where it is possible to do so. This could involve a sustained programme of outfitting on existing train stock.

Aviation

Lockdowns in response to Covid-19 meant that passenger volumes in the UK fell by 98.6 per cent[36] in April 2020 compared to April 2019. Globally, passenger volumes – in particular for international flights – fell by similar amounts over the same period.

In order to safely and effectively restart aviation globally, the International Civil Aviation Organisation (ICAO) published a framework to reduce the public-health risk to air passengers and aviation workers.

The risk-based framework looks at airports, aircraft, crew and cargo. For passenger flights, the ICAO guidance covers three primary risk areas for transmission: prior to departure, in-flight and leaving the aircraft.

31 https://www.bbc.co.uk/news/business-52822913

- **Prior to departure, at home and at the airport:** Given the likely modes of transmission, the highest-risk areas for passengers are ticketing and check-in, going through security checks (including queuing and using the security trays), waiting to board within the airport (retail areas, restrooms, seating areas), and the boarding process itself.
- **In-flight transmission:** Once on the aircraft, the highest-risk areas for transmission include touching surfaces such as the overhead compartments and in the lavatories, air circulation, in-flight services, queuing for the lavatories, and queuing to leave the plane.
- **Leaving the aircraft and the airport:** Once the aircraft has landed, the highest-risk points for transmission include queuing to leave the plane, queuing to pass through customs, waiting at baggage claim, and departing the airport.

Potential mitigation measures for air travel

The ICAO guidance suggests a risk-based, multi-layered strategy to reduce the public-health risk to air passengers and aviation staff, while also strengthening confidence among the travelling public. We call this the "Pre-Board/On-Board/Post-Board Model" of measures (see Annex for a full list of which countries have implemented specific mitigation measures).

Pre-flight notifications: Before passengers leave for the airport, airlines should use pre-flight notifications to provide advice to passengers, including: discouraging passengers with Covid-19 symptoms from travelling; requiring Covid-19 testing either on departure or arrival (such as in Austria, China and South Korea); advising on PPE requirements for the duration of a passenger's trip; providing reminders on hygiene (such as hand-washing); and advising on pre-flight screening and any in-flight procedures. In addition, passengers should be encouraged and/or incentivised to take as little luggage as necessary and to check-in luggage where possible.

32 https://www.nytimes.com/wirecutter/blog/can-hepa-air-purifiers-capture-coronavirus/

33 https://www.bccourier.com/is-it-safer-in-a-plane-in-front-of-corona-than-in-a-train/

34 https://metrarail.com/sites/default/files/assets/about-metra/news/bi-level/OTBLAugust2011.pdf

35 Item No. 30042, Air Pollution Abstracts, Volume 4, Issues 7-12, By United States. Environmental Protection Agency. Air Pollution Control Office, 1973

36 https://www.caa.co.uk/uploadedFiles/CAA/Content/Standard_Content/Data_and_analysis/Datasets/Airport_stats/Airport_data_2020_04/Airport_Statistics_Summary.pdf

Health screening and sanitation at the airport: As they do in managing security risks, airports (working with airlines and other service providers) have taken the lead in managing the risks of transmission within the airport, leaving the airlines free to focus on managing the transmission risks on the aircraft. This has taken a layered approach to managing and minimising the risk that an infected passenger proceeds through to the departure area, boards a plane or transmits the virus to another passenger. Actions airports have taken include:

- Conducting temperature screening as soon as passengers enter the airport and before check-in.
- Passengers with temperatures above 38 degrees C should be referred for follow-on screening and assessment.
- Airlines and operators should make self-check-in as quick and seamless as possible.
- Security trays should be disinfected after every use, either through UV filters or standard cleaning processes.
- All queues at check-in, security & boarding should maintain social distancing rules.
- Airport retail and restaurant areas should operate under the same operational and social-distancing rules as the rest of the economy.

Air circulation/filters on aircraft: According to the WHO[37], research suggests there is little risk of any communicable disease being transmitted on board an aircraft. Studies by the European Aviation Safety Agency show cabin air within an aircraft is changed every two to three minutes and passes through a HEPA filter that removes 99.97 per cent of particulates the size of coronavirus.

Transmission of infection may occur between passengers who are seated in the same area of an aircraft, usually as a result of the infected individual coughing or sneezing or by touch (direct contact or surfaces that other passengers touch). This is no different from any other situation in which people are close to each other, such as on a train or bus or in a theatre. Highly contagious conditions, such as influenza, are more likely to be spread to other passengers in situations where the aircraft ventilation system is not operating.

Thermal (and medical) screening: Research based on the early stages of the Covid-19 pandemic in Europe[38] and the US[39] indicates that entry/exit thermal screening is ineffective at preventing passengers from introducing coronavirus to a country. This is partly because a proportion of Covid-19

37 https://www.who.int/news-room/q-a-detail/air-travel-advice

cases is asymptomatic and a proportion of transmission happens before symptom onset.

However, experience from the SARS outbreak suggests that exit/entry thermal screening processes may help dissuade those who are ill[40] from travelling by air and enhance public confidence in flying. In addition, they provide a further means for providing specific risk communications[41] (for instance around quarantines or testing-and-tracing procedures) to passengers.

Geographic restrictions (for instance, transport corridors): According to the ICAO, most countries implemented some form of geographical restrictions on flights arriving in their country, with most imposing a blanket ban on aviation during the community transmission phase of the pandemic.

As countries have begun easing their lockdown measures, these geographical restrictions are shifting to risk-based distinctions that enable economic activity to restart while mitigating the risk of importing new cases. Singapore, for example, has negotiated a "fast lane" process with China, and has designated a set of Asia-Pacific countries whose travellers are no longer required to quarantine at designated sites.

- **Blanket travel bans.** Many countries still have a blanket ban on all domestic and international flights, with exceptions in place, for example, for citizens returning from abroad.
- **Risk-based categorisation of countries.** As countries begin to ease their lockdowns, many are moving to risk-based assessment, with passengers arriving from designated high-risk countries facing stricter entry requirements than those from lower-risk countries.
- **Negotiated reciprocal transport corridors.** Transport corridors, air bridges or travel bubbles are agreements between countries that allow citizens to cross borders without having to quarantine, and so allow trade and tourism to restart. Given the risk-based approach countries are taking, these agreements will divide countries along both economic and epidemiological lines. As such, James Crabtree of the National University of Singapore argues they could have "complex implications for trade, tourism and investment patterns".[42]

Testing prior to departure or upon arrival: Many countries require a negative test as a condition of travel and/or entry. Austria, for example, requires a negative test result from a test taken within four days of arrival,

38 https://www.easa.europa.eu/sites/default/files/dfu/EASA-ECDC_COVID-19_Operational%20guidelines%20for%20management%20of%20passengers_final.pdf

39 https://www.cdc.gov/mmwr/volumes/69/wr/mm6918e2.htm?s_cid=mm6918e2_w

and offers a test within the airport for arrivals. Others, like South Korea, require all arriving passengers to take a test upon arrival and require passengers to wait in designated testing facilities for the results.

Social distancing on planes: Research by Emory University following the SARS outbreak concluded that respiratory disease spread by droplets would likely be "limited to one row in front or in back of an infectious passenger."[43] According to a review of the literature by the IATA[44], aviation provides some natural protections, including the fact that people all face the same direction (rather than face-to-face); that they generally remain in their seat after boarding, except to visit bathrooms; that the seats provide some possible protections; and that cabin air flow from ceiling to the floor with HEPA filters is better at removing particulates than in public buildings with lateral air flow.[45]

Quarantines upon arrival: Many countries that have opted reopen their borders have implemented quarantine rules for arriving international passengers. The conditions of the quarantine vary, from requiring all international passengers to quarantine at a designated facility (such as China and Singapore) to allowing passengers to quarantine at home or at a hotel (such as the United Kingdom).

Wearing masks: Both the ICAO and the European Aviation Safety Agency (EASA) recommend that passengers wear masks during all parts of their journey. EASA suggests that masks should be replaced every four hours and recommends that passengers bring a sufficient supply of masks for the entire duration of their journey.[46]

Goggles or glasses: Virologist Dr Joseph Fair believes he caught Covid-19 through his eyes[47], having been on a crowded flight while wearing a mask and gloves and wiping down his seat. The US CDC has said that, "it may be possible that a person can get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose, or possibly their eyes."[48] The IATA's advice to airlines advises including goggles in their risk assessments, and crew on Philippines Air, AirAsia, Korean Air and Qatar Airways flights have started wearing goggles.[49] [50]

In-flight measures: The EASA recommends that airline crew have in place protocols to isolate and manage passengers who become symptomatic during the flight.

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40 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3294328/

41 https://institute.global/sites/default/files/inline-files/Testing%2C%20Screening%20and%20Tracing.pdf

42 https://foreignpolicy.com/2020/06/01/travel-bubbles-borders-flights-coronavirus-uk-france-air-bridge/

Securing international travel via digital identity and mobility credentials: Airports are the touchpoints between states with different vulnerabilities, health-system capacities and policy approaches. Instead of crude quarantines or border closures, we need a way to grant granular permissions for people to credibly assert that they can safely enter an airport or airplane. As we have written about in a previous paper, a properly implemented digital credential can act as a foundational layer of trust throughout international air travel, operating as a scalable and flexible way for states to manage risk at travel hubs. Some airports and testing and identity providers are already exploring this, but the use case is fast racing ahead of policy.

Crucially, digital identity infrastructure and mobility credentials could provide this assurance while precluding the risk of other apps or intimate medical records being required as a substitute – perhaps in an unlawful overreach. As we have previously set out, governments will need to develop a mass regime of Covid-19 testing that subsequently confers a mobility credential, a biometrically secured digital code (such as a QR code) authenticated by a testing facility that's stored on a person's phone and gives them permission to access specific settings. Airport security, airlines or border control could then scan this QR code simply using a smartphone or similar device, with each scan ensuring the issuer's signature is authentic and up to date. As we have also argued in a previous paper, rapid point-of-use antigen tests can increasingly be carried out quickly and with a high degree of accuracy. This would allow third parties to conduct them, including at airports, in turn allowing mobility credentials to be issued at the border and minimising risks in international travel.

This infrastructure does also present sensitive governance challenges that leaders must address for it to succeed, which we have explored in prior work on digital identity. Crucially, it will require primary legislation to set out how

43 https://scholar.google.com/scholar?hl=en&as_sdt=0%2C47&q=behaviors%2C+movements%2C+and+transmission+of+droplet-mediated+respiratory+diseases+during+transcontinental+airline+flights&btnG=

44 https://www.iata.org/contentassets/f1163430bba94512a583eb6d6b24aa56/covid-medical-evidence-for-strategies-200609.pdf

45 https://onlinelibrary.wiley.com/doi/abs/10.1111/ina.12578

46 https://www.easa.europa.eu/sites/default/files/dfu/EASA-ECDC_COVID-19_Operational%20guidelines%20for%20management%20of%20passengers_final.pdf

47 https://www.npr.org/sections/goatsandsoda/2020/05/22/861299427/coronavirus-faqs-can-i-catch-it-through-the-eyes-will-googles-help

48 https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html

49 https://www.iata.org/contentassets/df216feeb8bb4d52a3e16befe9671033/iata-guidance-cabin-operations-during-post-pandemic.pdf

50 https://edition.cnn.com/travel/article/qatar-airways-full-body-cover-protection/index.html

credentials are used in practice, in order to secure broad-based public support, and political sponsorship from a senior minister to marshal the different parts of government towards a common goal. International travel in particular will likely require countries to work together to agree internationally interoperable credentials. But with many countries facing the same challenges, the need isn't going away. Governments should get ahead of the challenge to build a system that is secure, user-centric and commands wide public support.

Conclusion

Restarting transportation, either domestically or internationally, in order to move millions of people around the world without any infection risk is prohibitively difficult. The aim, therefore, must be to look at the risk of transmission in each form of transport and introduce measures to mitigate these risks. Many of these are implementable now, while there are a number of measures, such as vehicle design, that require more time and resources. These should be considered in the context of mitigating against future pandemics.

For domestic transport we recommend the use of face masks and underline the importance of social distancing, which, critically, will require a significant reduction in demand on services.

Rail companies have suggested that passenger capacity on trains may need to be reduced by 70 to 90 per cent if 2-metre social distancing is enforced and by 55 per cent if 1-metre social distancing is enforced. TfL has said passenger capacity on tubes and buses may only be 13 to 15 per cent of normal levels for the same reasons.[51]

Most businesses will need to therefore take a pragmatic stance on their employees ideally working from home for the medium term, or at least working to flexible hours.

For international travel we also recommend masks, with rapid testing and mobility credentials that sit atop a secure and user-centric digital identity infrastructure made available to allow people to prove they are safe to travel.

Recommendations

1. **Prevent transmissions among passengers and protect staff through masks and shields.**

   For all forms of travel, there are some general measures that should be implemented as a matter of course. To ensure these measures are feasible and implementable, industry should work with governments and trade bodies now to get the infrastructure and any necessary equipment in place. These measures include:

   - Masks to prevent passengers from transmitting the disease. These should be mandatory and worn in all public spaces where social distancing is not possible or is severely hampered. This includes

planes, trains, buses, ports and terminals. Speaking to us about this paper, Jeremy Howard, co-founder of Masks4All, said: "Public transport is one of the most dangerous settings for Covid-19 transmission – indoors, close contact, for a sustained period, where distancing may not be possible. Wearing a mask is the best way to reduce the chance of infection in such a setting. There are many countries in East Asia where high density train transit has continued throughout the pandemic, and transmission rates have remained low. Mask use seems likely to be a key factor for this."

- Face shields to protect workers interacting with the public on a continuous basis. Transparent face shields are a protective measure for the wearer. Unlike a mask, which is used to prevent the spread of the virus, a shield stops droplets from reaching the wearer and should be worn by security staff, bus drivers, tube station staff and so on.

2. Fundamentally change how and why people travel in order to flatten transport usage.

Coordination between businesses and government is essential to removing the rush hour. With proper alignment and consideration around start times of workplaces and schools, along with a general shift in working patterns, the rush hour simply need not exist. The shift in working culture, exacerbated by Covid-19, could see the burden on public transport become much more evenly spread if managed properly. This reduces the exposure of passengers and allows important measures such as social distancing to be more effectively implemented.

Businesses should also take this opportunity to think about their working methods medium to long term. Many organisations have found they have worked as effectively, if not more effectively, working remotely. Both Twitter and Facebook have, for instance said that staff can continue to work from home long term. Other companies such as Google, Microsoft, Morgan Stanley, JP Morgan, Capital One, Slack, Amazon, PayPal and SalesForce have also extended their working-from-home options.[52]

3. Utilise testing to restore confidence among travellers and to identify and isolate anyone carrying Covid-19, conferring credentials linked to a secure and user-centric digital identity to allow people to access travel safely.

Testing should be introduced at all major ports of entry and exit, and this should be internationally coordinated with standards recognised.

51 https://www.ifs.org.uk/publications/14844

Positive antibody and negative antigen tests would confer a mobility credential linked to a digital identity, allowing specific individuals to prove if they are safe to travel.

4. **Adopt innovative engineering solutions to redesign and repurpose modes of transport to become Covid-safe and mitigate against future pandemics.**

   There are known innovations out there that have already made some modes of transport relatively safe when it comes to Covid-19. These include the use of HEPA filters; this technology, widely available, should be rolled out to other transport types – including trains. A medium- to long-term plan for engineering craft which is conducive to social distancing or which allows for better filtration should be drawn up, with innovators incentivised to design and build new transport. Such innovations would be useful now but also an investment in future preparedness in the event there is another pandemic.

5. **Introduce the Pre-board/Onboard/Post-Board Model of measures (see Annex below) to offer safe and efficient air travel now.**

   These comprehensive measures have been developed by the ICAO and adopted in full by a number of countries. Wholesale adoption will allow for safer transit between more countries and reassurance in travel from one destination to another. These measures should be adopted and implemented in full by all countries and supported by airlines.

52 https://www.forbes.com/sites/jackkelly/2020/05/24/the-work-from-home-revolution-is-quickly-gaining-momentum/#288010ca1848

Annex
The Pre-board/Onboard/Post-board Model

1 Prior to arriving at the airport

Transmission risks

Symptomatic and asymptomatic passengers head to the airport for their flight.

Containment options

Pre-flight notifications (e.g. 24 hours before flight) from airlines including:

- Any travel restrictions for passengers displaying Covid-19 symptoms.
- PPE required for travel, such as bringing enough masks to last the duration of the trip.[53]
- Reminders on travel hygiene, including washing hands, sneezing or coughing into elbows, and maintaining 2-metre distance.
- Any pre-flight screening, such as thermal screening or rapid antigen/antibody tests.
- Requirements on a recent negative Covid-19 antigen test or an immunity certificate.
- Reminders that only passengers can enter the airport.
- Any restrictions on carrying hand luggage.
- Advising on any in-flight procedures for passengers who present symptoms during flight.

Passengers should be encouraged and/or incentivised to take as little luggage as necessary and to check-in luggage where possible.

53 The European Aviation Safety Agency recommends replacing masks every four hours of travel time.

Countries using options

Require medical certificate or test to travel: Austria (<4 days old), Bali, Bahrain (upon arrival), Bolivia (<14 days old), Bosnia and Herzegovina (<2 days old), Cambodia (<3 days old and test upon arrival), China (<3 days old if travelling form South Korea) Cyprus (<3 days old), French Polynesia (<3 days old), Greece (<2 days old or test and quarantine on arrival), Guam (<7 days old), Guatemala (<3 days old), Iceland (upon arrival or 14-day quarantine), Indonesia (rapid test <3 days old or PCR <7 days old), Iran, Jamaica, Japan (upon arrival), Kazakhstan (upon arrival), Lebanon (on arrival, results in 24 hours); Malaysia (<3 days old), Nicaragua, Paraguay, the Philippines (upon arrival), Rwanda (either PCR <3 days old and again on arrival with results in 72 hours, or two tests upon arrival); Laos (< 3 days old), Seychelles (<2 days old), Slovakia (upon arrival), Singapore (during quarantine), South Korea (upon arrival), Sri Lanka (<3 days old or upon arrival), Turkey (upon arrival), UAE, Venezuela (upon arrival)

2 At the airport, prior to boarding

Transmission risks

Symptomatic and asymptomatic passengers proceed to gate.

Touching infected surfaces at ticketing, check-in and baggage check; security checkpoints; in-airport retail and restaurants; waiting areas; restrooms; and boarding queues.

Containment options

As they do in managing security risks, airports (working with airlines and other service providers) should take the lead in managing the transmission risks within the airport, leaving the airlines free to focus on managing the transmission risks on the aircraft. This should take a layered approach to managing and

minimising the risk that an infected passenger proceeds through to the departure area, boards a plane or transmits the virus to another passenger. Actions should include:

- Conducting temperature screening as soon as passengers enter the airport and before check-in.
- Passengers with temperatures above 38 degrees Celsius should be referred for follow-on screening and assessment.
- Airlines and operators should make self-check-in as quick and seamless as possible.
- Security trays should be disinfected after every use, either through UV filters or standard cleaning processes.
- All queues at check-in, security and boarding should maintain social distancing rules.
- Airport retail and restaurant areas should operate under the same operational and social distancing rules as the rest of the economy.

Countries using options

Health screening/tests at airport: Albania, Australia, Austria (optional), Bahrain, Bangladesh, Benin, Canada, China, Ecuador, El Salvador, Georgia, Hong Kong, Iceland (option to download app), Iran, Japan, Kuwait (track & trace app), Laos, Malaysia (for crew), Macao, Malaysia, Poland, Korea (download app), Rwanda, Singapore, United States (Puerto Rico)

3 On board

Transmission risks

Asymptomatic transmission to other passengers via air circulation.

Touching infected surfaces such as overhead compartments, lavatory facilities, on-board services; queuing for the lavatory, and queuing to leave the aircraft.

Passengers becoming symptomatic on the plane.

Containment options

Even though cabin air is fully renewed every two to three minutes, airlines and operators should consult aircraft manufacturers to understand the options for improving the flow of air through the aircraft. While retrofitting aircraft with new systems is not a viable option, there could be other options, such as reducing the amount of recirculated air, which could reduce the likelihood of transmission of the virus.

Airlines and their crew should follow all hygiene and cleaning guidelines. This could include minimising the amount of carry on-luggage to reduce touching of overhead bins, a reduction in on-board services (e.g. duty-free and food/drink services), and frequent cleaning of commonly touched places.

For passengers becoming symptomatic during the flight:

- Minimise the contact between the symptomatic passenger and the cabin crew and other passengers. This could include isolating the passenger (and their travelling companions) in the last two rows of the plane.
- Notify the destination airport of the passenger's status.
- Identify passengers seated within two seats in every direction of the symptomatic passenger, as they may need to be tested and quarantined if the suspected case is confirmed.

Cabin crew receive appropriate stocks of PPE both to wear and to treat symptomatic passengers.

Countries using options

Masks: most countries/airlines require a mask on board.

Separation: Ecuador (6 feet), Italy (1 metre), Netherlands (1.5 metres), Spain (up to 50% capacity), Sri Lanka (1 metre)

After leaving the plane

Transmission risks

Asymptomatic passengers leave airport and head into community untraced.

Containment options

All passengers are asked to remain in their seats until their rows are called to leave the plane. Disembarkation should proceed in a manner that can ensure physical distancing and avoid queuing.

All passengers are required to undergo additional screening including temperature checks or rapid antigen and antibody tests after leaving the plane and before leaving the airport (or designated area). Alternatively, passengers could be required to show the results of a recent antigen or antibody test.

All passengers are required to register for and participate in national track-and-trace system.

Risk-based restrictions on flights from certain countries.

Countries using options

Geographical restrictions: Angola; Argentina; Australia; Austria; Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belgium, Belize, Bolivia, Bosnia & Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Cambodia, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Côte d'Ivoire, Cuba, Cyprus, Denmark, Djibouti, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Iraq, Ireland, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kiribati, Kuwait, Kyrgyzstan, Laos, Latvia, Lebanon, Lesotho, Liberia, Luxembourg, Macau, Madagascar, Malaysia, Maldives, Malta, Mexico, Mongolia, Montenegro, Morocco, Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Pilau, Panama, Papua New Guinea, Paraguay, Peru,

Philippines, Poland, Portugal, Qatar, Korea, Moldova, Romania, Russia, Rwanda, St Kitts & Nevis, St Lucia, St Vincent & the Grenadines, Samoa, Saudi Arabia, Senegal, Serbia, Seychelles, Singapore, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, South Sudan, Spain, Sri Lanka, Sudan, Suriname, Sweden, Switzerland, Tajikistan, Thailand, The Republic of North Macedonia, Timor-Leste, Togo, Tonga, Trinidad & Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, UAE, United States

Passenger location form/health declaration cards: Argentina; Australia; Austria; Azerbaijan, Belgium, Bosnia & Herzegovina, Brunei, China, Costa Rica, Denmark, Finland, France, Germany, Iceland, Iran, Ireland, Italy, Japan, Kenya, Latvia, Montenegro, Netherlands, Nicaragua, Norway, Poland, Portugal, Romania, Samoa, Serbia, Singapore, Slovakia, Solomon Islands, Spain, Sri Lanka, Sweden, Tonga, Turkey, United Kingdom

14-day quarantine: Albania, Antigua and Barbuda, Argentina, Armenia, Australia, Austria (unless recent medial certificate is provided); Bangladesh, Bolivia, Botswana, Brunei, Bulgaria, Canada, Chile, China, Costa Rica, Cyprus, Denmark, Ecuador, Ethiopia, Fiji (28 days), Finland, France, French Polynesia, Georgia, Germany, Greece, Guatemala, Hong Kong, Iceland, India, Iran, Ireland, Italy, Jamaica, Japan, Kazakhstan, Kyrgyzstan, Lithuania, Macao, Madagascar, Malaysia, Maldives, Montenegro, Netherlands, New Zealand, Nicaragua (15 days), Norway (10 days), Pakistan, Palau, Panama, Paraguay, Peru, the Philippines, Portugal, Romania, Russia, Rwanda, Samoa, Saudi Arabia (crew), Serbia (28 days), Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, South Africa (21 days), South Korea, Spain, Taiwan, Thailand, Turkey, Ukraine, United Kingdom, United States (by state), Uruguay, Vietnam, Venezuela (15 days)

Require medical certificate or test to travel: Austria (<4 days old), Bali, Bahrain (upon arrival), Bolivia (<14 days old), Bosnia and Herzegovina (<2 days old), Cambodia (<3 days old and test upon arrival), China (,<3 days old if travelling form South Korea) Cyprus (<3 days old), French Polynesia (<3 days old), Greece (<2 days old or test and quarantine on arrival), Guam (<7 days old), Guatemala (<3 days old), Iceland (upon arrival or

14-day quarantine), Indonesia (rapid test <3 days old or PCR <7 days old), Iran, Jamaica, Japan (upon arrival), Kazakhstan (upon arrival), Lebanon (on arrival, results in 24 hours); Malaysia (<3 days old), Nicaragua, Paraguay, the Philippines (upon arrival), Rwanda (either PCR <3 days old and again on arrival with results in 72 hours, or two tests upon arrival); Laos (< 3 days old), Seychelles (<2 days old), Slovakia (upon arrival), Singapore (during quarantine), South Korea (upon arrival), Sri Lanka (<3 days old or upon arrival), Turkey (upon arrival), UAE, Venezuela (upon arrival)

Health screening/tests on arrival: Albania, Australia, Austria (optional), Bahrain, Bangladesh, Benin, Canada, China, Ecuador, El Salvador, Georgia, Hong Kong, Iceland (option to download app), Iran, Japan, Kuwait (track & trace app), Laos, Malaysia (for crew), Macao, Malaysia, Poland, Korea (download app), Rwanda, Singapore, United States (Puerto Rico)

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