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REVIEW

COVID-19 and public transport: an overview and recommendations applicable to Latin America

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Abstract

The article presents a general overview on COVID-19 transmission in the context of public transport, particularly applicable to decision making in Latin America. Based on recent findings on COVID-19 transmission and the relative importance of each factor (droplets, fomites, and aerosol routes) in such transmission, we seek to update the discussion on the topic that has generally been based on social distance as the only parameter for reducing the risk of transmission and broadens the vision to integrate ventilation, users' behavior (mask and eye protection use, silence while in the transport system) and travel distance. Recommendations to improve mobility conditions reducing the risk of COVID-19 contagion are provided.

COVID-19 y transporte público: una revisión y recomendaciones aplicables a América Latina

Resumen

El artículo presenta una revisión de transmisión de COVID-19 en el contexto de transporte público, con aplicación particular para toma de decisiones en América Latina. Con base en los hallazgos recientes sobre transmisión de Covid-19 y la importancia relativa de cada factor (gotículas, fómites y rutas de aerosoles) en dicha transmisión, buscamos actualizar la discusión sobre el tema que generalmente se ha basado en la "distancia social" como parámetro único de reducción de riesgo de transmisión y amplía esta visión para integrar la ventilación, el comportamiento de usuarios (uso de mascarilla, protección ocular, silencio), y la distancia de viaje. Se indican al final recomendaciones para mejorar las condiciones de movilidad en general sin aumentar el riesgo de contagio de Covid-19.

Background

As of October 1st, 2020, the region of the Americas is the epicenter of the COVID-19 pandemic and the most affected region in the world. South America holds the highest mortality rate (587/million) followed by North America (517/million) and Europe (297/million)[1]. Even before the COVID-19 pandemic, Latin America has been facing large public health and sustainability challenges, including being the most urbanized region in the world (80% of Latin Americans live in cities), having a high population density, high levels of air pollution, approximately 50% of workers in the informal sector[2], a rapidly increasing prevalence of chronic non-communicable diseases and a background of marked social inequalities[3]. The COVID-19 pandemic has exacerbated these problems, forcing decision-makers, government officials, and academics to think not only about how to face the pandemic from the health systems perspective, but also how to take into account social and infrastructural aspects. In particular, the role of cities on inclusion and equity, environmental sustainability, and security emerge as relevant issues.

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In the face of the COVID-19 pandemic, defining how public transport operates to prevent the spread of the virus is essential for adequate mitigation and risk management. The high density and mixing levels of people that characterize public transport systems, fundamental for the operation of most cities, could convert these systems into places prone to a rapid spread of the virus if proper measures are not taken. However, restrictions on occupation and financial problems of the system may imply the deterioration of the service or the abandonment of routes, and it has been shown that in areas without adequate coverage of formal transport, informal services are the only means of mobility for the lower-income population[4]. Alternatives such as bike-taxis, motorcycle taxis or similar may imply greater transmission risks since it is less likely that strict biosafety protocols are followed. Likewise, the massive individual motorization (purchase of private cars and motorcycles) in response to the pandemic can result in serious consequences in public health and use of hospital resources due to the degradation in air quality, sedentary lifestyle and accidents that this implies; all of this in addition to the effects on congestion, stress and productivity[5,6,7].

Public Transportation and social integration in Latin America

In Latin America, it is estimated that 68% of trips are made using public transport or shared transport systems[8], while individual motorized trips are a minority and also generate negative effects in terms of equity, pollution, road safety, and health[9]. Furthermore, travel patterns in the region imply longer trips and worse conditions for low-income people, who in turn are more dependent on public transportation. As per a publication from Brookings Institute[10], there is a direct relationship between lower-income population and their need to work in person (those with less income tend to have manual or face-to-face jobs, those with higher income working in non-occupational jobs). Based on this, and as it has already been made clear in various contexts, public transport is one of the most important services in a city as it ensures the access of the lower income and most vulnerable population to their places of work and therefore to their livelihood, as it is the case with domestic service workers, who travel mainly between low- and high-income residential areas, and are captive users of public transportation[11].

Cities in Latin America have experienced a phenomenon of recent acceleration of urban sprawl[14] and as a consequence homes, jobs, schools, and other destinations are increasingly farther from each other which results in long travel distances[15]. The idea of improving public transport has been a priority in many of the countries of the region, but there has never been any reflection on the impacts on the mobility of the most vulnerable in a pandemic that restricts formal public transport services to reduce contagion rates.

Figueroa[16] defines the transportation situation in Latin America from a middle class that quickly acquired their own car, and a lower level of income that is divided between those who can access an established public transportation system and those who are forced to opt for more informal, degraded and insecure means and in a pandemic this situation is even more complex. For this reason, there are constant attempts to make the public transport system accessible, safe and efficient in terms of reducing not only contagion but also allowing the poorest to reach their homes and workplaces safely.

Social integration and cohesion are measured, among others, based on the equal opportunities that its inhabitants have to participate in city life[12]. Thus, the processes of social cohesion include allowing access for all citizens to the different activities the city offers, one of them being the opportunity to travel. It is clear that access to employment opportunities, places of residence, and spaces where many essential services are offered depend on transport conditions[13]. In other words, mobility problems can often aggravate poverty and hence social exclusion. Those who must move even with the virus circulating are precisely the people with the lowest income, which is why the impact of the urban transport system of a city with lower income population is very relevant and mechanisms must be found to reduce the risk of contagion and allow safe mobility and increase that gap that already exists under "normal" (i.e. "non-COVID-19") conditions.

COVID-19 and Transportation in Latin America

Pandemic control strategies in many Latin American countries have included restrictions on transportation that have varied from the total closure (as in the case of the Dominican Republic)[17] up to restrictions in occupancy (as is the case in Colombia and Argentina, among others). However, regardless of restrictions, all countries experienced reductions of more than 50% in public transport use at the beginning of the pandemic, around the second half of March 2020 and no countries have returned to pre-pandemic levels. Of notice, Brazil and Mexico show a less marked reduction compared to the rest of Latin American countries as well as a faster return to high levels of use (Figure 1).

Mechanisms of transmission of SARS-COV-2 in transport systems

The most important mechanisms of contagion of SARS-CoV-2 for transport systems are[18,19]:

- Contact with common surfaces (fomite)
- Contact with respiratory droplets (5-10 μm in diameter)
- Inhalation of aerosols with nuclei droplets (<5 μm in diameter)

Fomites and droplets

Social or physical distancing helps reduce the transmission of respiratory droplets containing SARS-CoV-2 and slows the incidence of the disease by reducing the chances of possible viral exposure. The current consensus regarding the transmission of SARS-CoV-2 is that it is transmitted from

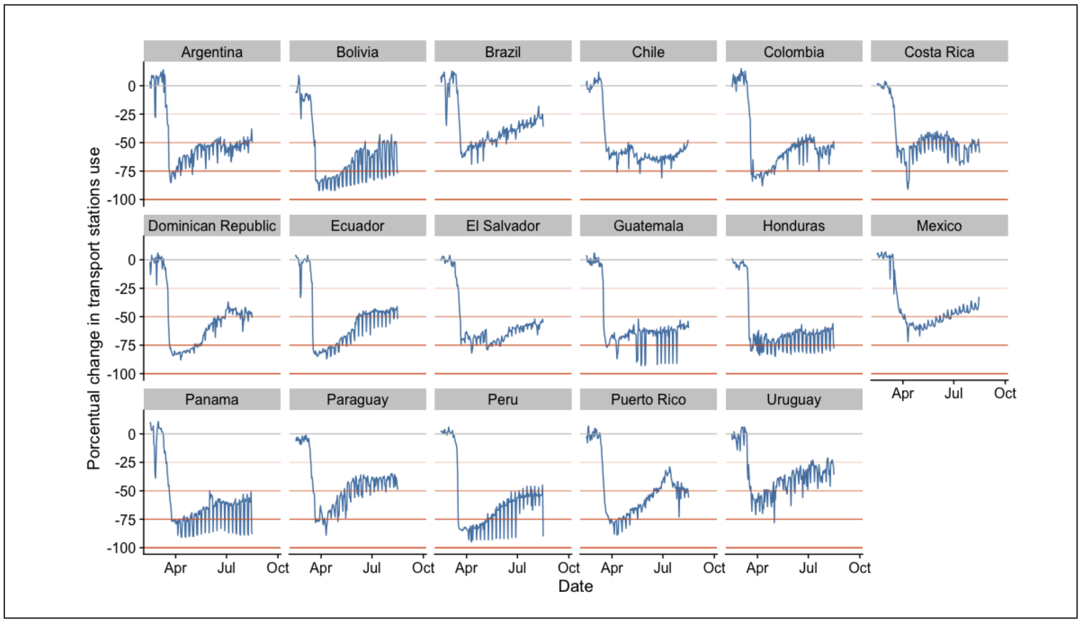

Figure 1. Trends in change of transport use in Latin America (Google mobility). Own elaboration

person to person through respiratory droplets[21]. However, SARS-CoV-2 has also been shown to be viable on a variety of common surfaces in ambient conditions up to 96 hours after exposure[22]. Other authors demonstrated that SARS-CoV-2 remains on average for approximately 6.8 hours on plastic surfaces and approximately 5.6 hours on stainless steel surfaces[23] This in addition to studies indicating that it can remain in the environment specifically in places with poor ventilation and inadequate air conditioning systems.

Respiratory secretions or droplets expelled by infected people can contaminate surfaces and objects, resulting in fomites (contaminated surfaces). On these surfaces, it is possible to detect the SARS-CoV-2 virus or RNA for periods ranging from hours to days, depending on the environment and the type of surface. Therefore, it is also possible that SARS-CoV-2 is indirectly transmitted by touching contaminated objects because people can touch their mouth, nose or ears after touching an object or surface[19].

Inhalation of aerosols

Although at first it was said that transmission via aerosols was not the preferred route of infection, recent studies have shown that this is a viable and even a predominant mechanism[24,25] and that it explains that closed spaces are about 20 times more likely to promote super-spreading events. Likewise, and it is a very relevant argument for cities in Latin America, air humidity increases the viability of the virus in aerosols for longer periods of time.

The main sources of respiratory particles in the aerosol size range (below 100 microns) are coughs and sneezes[21,26]. However, normal breathing and speech are important sources if we also take into account that they are more frequent and sustained activities. In fact, four minutes of breathing or talking generates the equivalent of 30 seconds of sneezing or singing[27,28]. Therefore, as an additional measure, it is important to limit speaking and singing to a minimum in public transport to reduce the generation of aerosols[29]. Wearing face masks and being quiet while traveling reduces the generation and exposure of aerosols.

Air renewal

Ventilation must achieve air volume renewal while avoiding high speeds (4 km/h to 15 km/h) near the nose or mouth of the passengers since large droplets may travel greater distances (up to 6m)[30], therefore eliminating the benefits of ventilation. An effective air renewal system allows a shorter distance between passengers without increasing the risk of contagion as shown in the next section. However, it is important to renew the air in the cabins. Hence it is very important to open windows in order to minimize or eliminate the use of recirculated air[31] if forced air mechanisms do not exist.

Distance and Duration of the journey

Several studies have suggested duration of the journey is a key risk factor. A recent study in India found a high secondary attack rate (79%) in individuals traveling in close contact to an infected person for ≥6 hours[32] Other studies have arrived at similar findings in long trips[33,34].

Risk factors for transmission to passengers

According to the literature reviewed and the vehicle ventilation models developed by members of this group [35], it is possible to reduce the risk of contagion in a public transport vehicle taking into account five factors:

1. **User behavior:** in silence, with properly adjusted mask and eye protection at all times. Silence is important because four minutes of dialogue are equivalent to 30 seconds of sneezing[28].

2 **Type of ventilation system** (natural, air conditioning), and characteristics of air renewal (the probability of contagion is reduced when there is a frequent air renewal).
3 **Closeness between contacts:** distance between people depending on ventilation and duration of the trip (between worse ventilation and longer duration, greater distance).
4 **Duration of the trip**: short trips generate less exposure; after 15 minutes there is a greater risk.
5 **Frequent cleaning of surfaces**: following the rules already established by several health organizations at the government and multilateral level[36,37].

Public transport vehicles with the lowest risk[38–40]:

- Those in which travelers keep in silence and always with eye protection and adequate and well-placed masks, and these protections are used throughout the journey and they are not removed. Also, no behaviours such as eating or talking on the phone.
- The vehicle has good ventilation, meaning the air is renewed 100% in one minute or less.
- Passengers enter and leave the stations and vehicles in an orderly manner, respecting distancing measures.
- People have an adequate distance for the level of ventilation and the duration of the trip. One meter between people is generally assumed adequate, but it may be less if the ventilation conditions are good and if everyone uses protective elements.
- The trips are short (less than 15 minutes).
- Surfaces have been cleaned frequently, if possible after each journey.
- Passengers entering and exiting stations wash their hands and clean their cell phones.
- Maximum occupancy indicators (see Table 1) are followed.

Maximum occupancy

The Universidad Nacional de Colombia (Medellín campus) conducted a series of simulations to estimate maximum occupancy in transit systems in order to keep appropriate distance based on different levels of transmission (Table 1). These estimates of optimal maximum occupancy can be extended to various zones, routes, or lines.

We present six case studies about specific public transport systems and the measures that can be recommended according to the current evidence of how SARS-Cov-2 transmits in public transport systems (See the box).

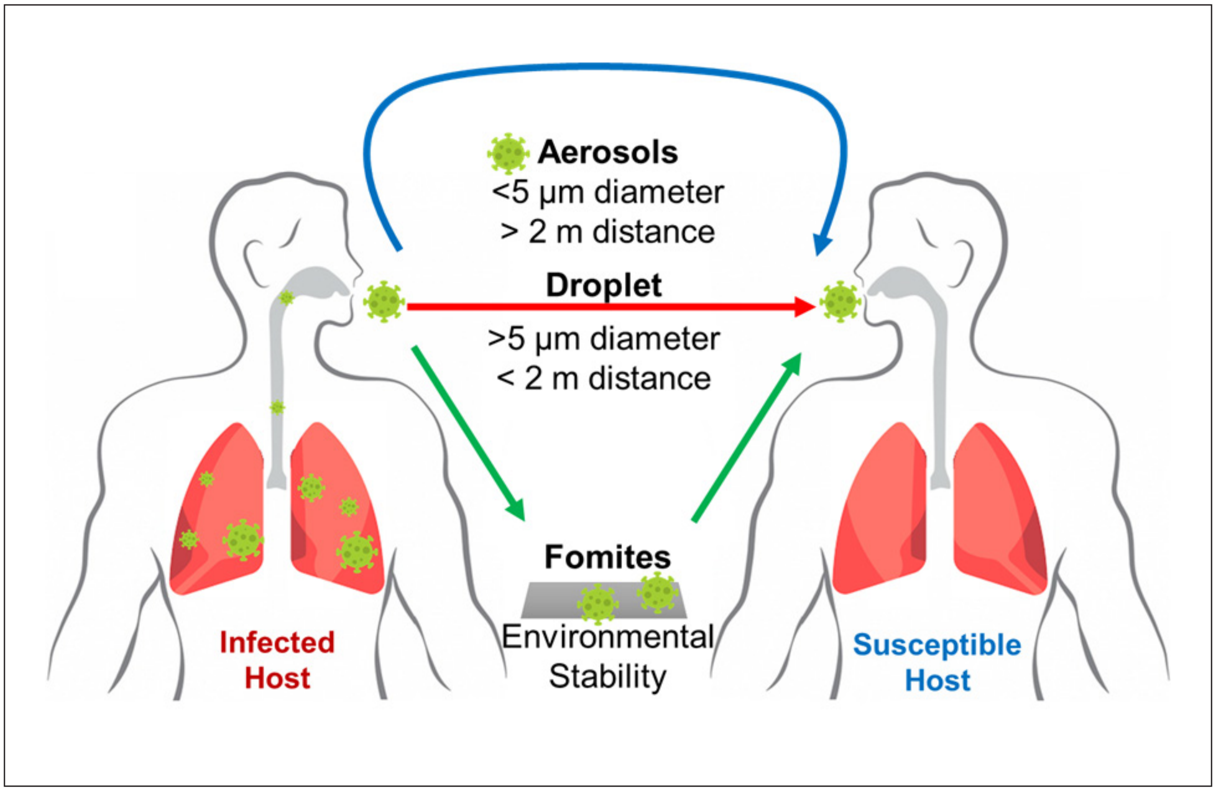

Figure 2. Transmission mechanisms of SARS infection Cov2 (Adapted from: [20])

Table 1. Suggested maximum occupancy of public transportation systems according to transmision levels. Occupancy is defined in this case as the proportion of the average occupancy of 2019. The colors correspond to the four discrete levels of transmission affectation as indicated by Colombia's Ministry of Health[41], and the rows show the percentage of occupancy according to the number of current users divided by the users' historical average of 2019.

Type of vehicle / Transmission level	Red (High transmission)	Orange (Moderate transmission)	Yellow (Low transmission)	Green (No COVID)
Trains and trams	40%	55%	70%	85%
Articulated buses	40%	50%	60%	70%
Standard buses (not articulated)	40%	50%	60%	70%
Cables	25%	37%	50%	63%
Conventional bus	40%	45%	50%	55%
Van	40%	45%	50%	55%

BOX. Case studies. Transmission in different types of vehicles

Based on the literature consulted and simulations and tests on vehicles made by the National University (Antioquia), the following can be said about five example cases that are organized from the lowest to the highest risk:

Medellín Metro: It has no air conditioning and the air is renewed with a time constant of three minutes and 30 seconds. It also renews the air at least 16.5 times every hour and the trips have an average duration of 15 minutes and 90% do not exceed 25 minutes. In simulation exercises, it was estimated that its capacity could be increased substantially without increasing risks substantially. Vehicle tests gave similar results.

Bogotá buses (articulated, Zonal SITP and Feeders): the ventilation of a Bogotá standard bus with open windows would not generate a greater risk since its air renewal rate is 4 times every hour -it is renewed every 15 minutes and 45 seconds (according to Colombian Standard NTC 4901-3, item 5.11.4[42]). Some vehicles have a more efficient system that renews the air about 6 times in an hour (100% renewed every 10 minutes and 15 seconds) based on tests performed on the vehicle. Trips are generally between 20 and 40 minutes, sometimes longer than an hour.

Medellin Streetcar: has air conditioning and its air recirculates 66%, is renewed 33% (time constant to be determined). Trips of average duration of 10 minutes.

Urban public transportation buses: despite having skylights, they have a renewal time of about 20 minutes or three times in an hour. Their trips are relatively short (20 minutes). It is crucial to use auxiliary air circulation mechanisms, and sufficient air renewal could help to increase the occupation.

Inter-municipal bus in hot climates: with air conditioning (the NTC standard associated with these vehicles is insufficient and only recommends 20% air renewal) and smaller windows. Long travel time and close contact represent the highest risk of contagion, in addition to its ability to "transport the virus" between municipalities.

Decision making for transportation systems during COVID-19 pandemic

Based on current evidence of transmission and on the importance of keeping functional means of transport, NUMO has developed a decision tree to guide decision-making in different situations and in terms of the actions to be taken based on the factors described here. Policy decisions should start by improving the risk factors that may operate at the infrastructural level such as ventilation and air renovation and distance and then at the individual level such as face mask use, silence and duration of the trip. (Figure 3).

Conclusions

- An adequate and safe reduction of the restrictions on the operation of public transport accompanied by appropriate biosecurity measures in Latin America will be crucial to allow the economic recovery of lower-income population groups. This is crucial to make a more equitable transition as they represent the higher proportion of users given the structural difficulty of replacing their face-to-face jobs by teleworking.
- The key factors to take into account for the safe operation of public transport are ventilation, user behavior (use of mask and eye protection), user silence, and travel distance. These factors make possible a smaller distance between passengers than the typically recommended (1-2m).
- If the factors presented here are not adopted promptly, public transportation could become an important site of infection. But the evidence is inconclusive on the effectiveness of suspended public transport systems as a preventive measure of the pandemic[45]. Taking into account the adverse effects, the closure of public transport services is generally not recommended.
- As a complementary measure to public transport and the improvement of its service, it is important to remember that measures such as staggering schedules, teleworking, and promoting non-motorized modes are recommended as a permanent measure, even when the health emergency is over. Given the direct and indirect positive effects of these measures. A significant proportion of the population can benefit from reducing the pressure and demand on public transport and make it easier to operate properly.
- This is an opportunity to make public transport more equitable and fairly competitive in Latin American cities. Since lower occupancy in peak periods, and higher fre-

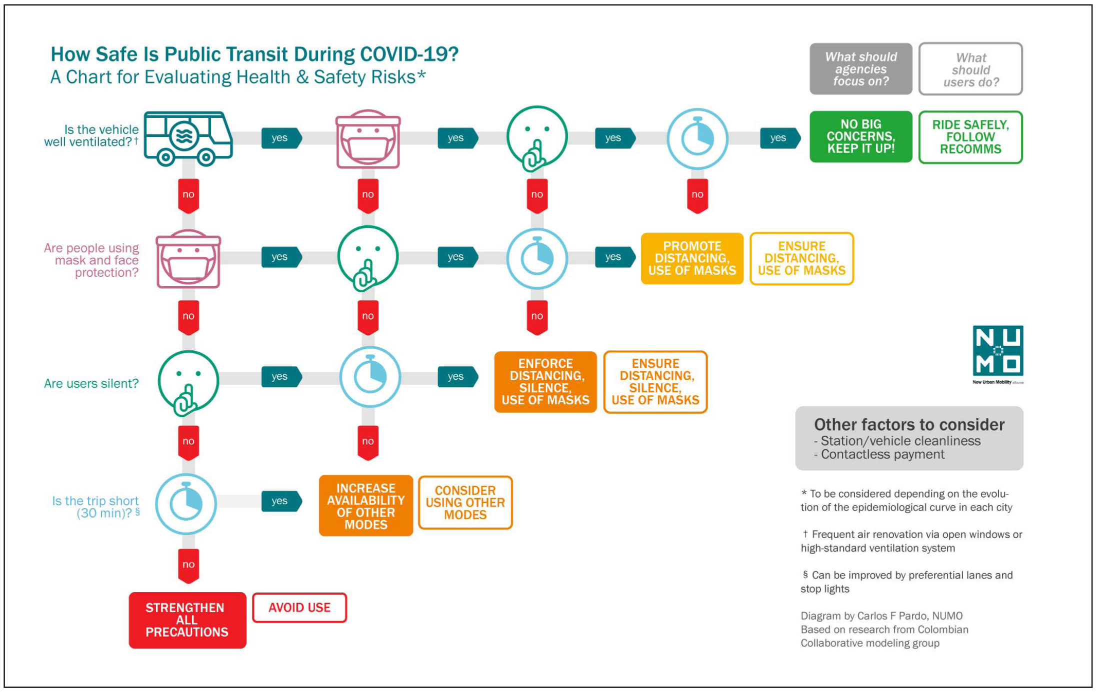

Figure 3. Suggested decision tree to reduce the risk of contagion in public transport[44].

quencies in off-peak periods make the system more attractive for users of individual motorized modes such as cars and motorcycles.

- It is important to clarify that these recommendations are related to the users of the system, since **drivers are more exposed** to the risk of contagion (due to a longer duration of exposure and closeness to many more people) and must follow strict biosafety protocols, and operators and system managers take the greatest precautions to reduce their risk.
- It is recommended that, without neglecting the measures to avoid possible crowds and respect the physical distance in mass public transport, that **the factors of personal care, ventilation, and disinfection described here be given greater importance and dissemination**.

Ethical disclosures

Protection of human and animal subjects. This research do not used animal nor human material.

Confidentiality of data. Not applicable

Right to privacy and informed consent. No applicable

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