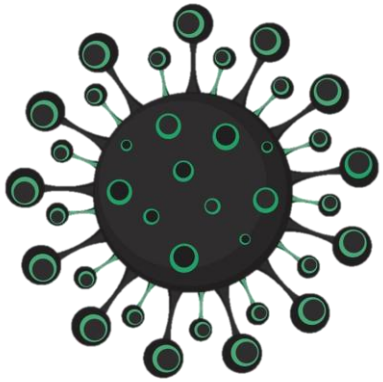
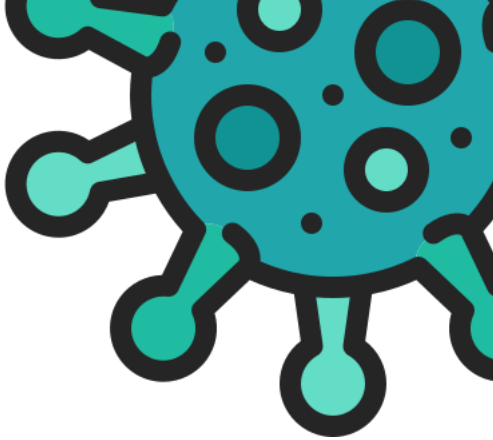


Pandemic safe-design for metro trains

Emilie Maillard, Lorenzo Prato



01 Introduction

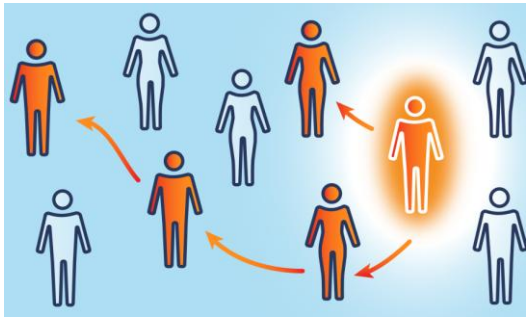
Hazard description and health risks

Pandemics and Epidemics
Definitions

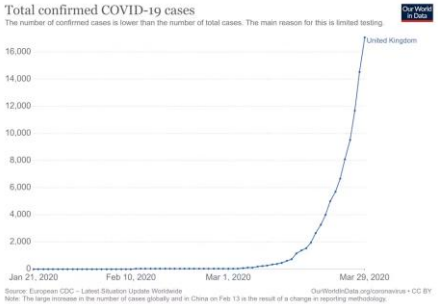
Epidemic: unexpected increase in the number of disease cases in a specific geographical area. (*CDC*) [1]

Pandemic: worldwide spread of a new disease. (*WHO*) [2]

Key characteristics to define a pandemic/epidemic [3]:



Infectious disease



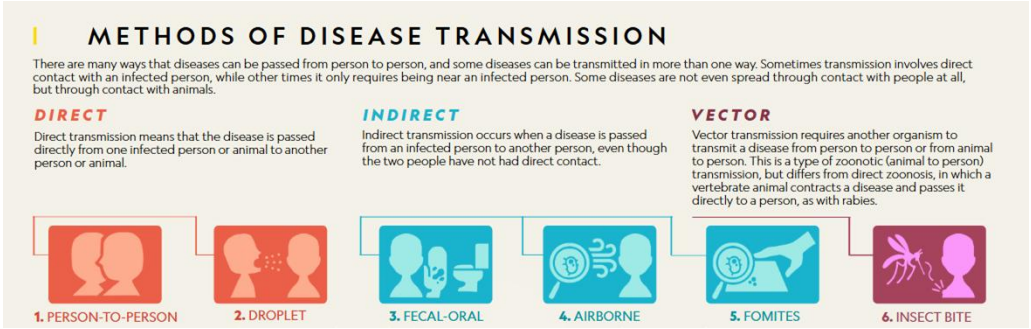
Exponential Growth Rate

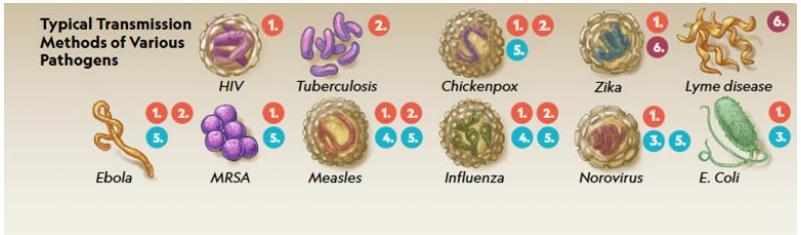
Covered Area

Pandemics and Epidemics
Transmission

There are many ways that a disease can be passed from person to person, and some of them can even be transmitted in different ways [4]

- Direct transmission
  - Person-to-person
  - Droplets
- Indirect transmission
  - Fecal-oral
  - Airborne
  - Fomites
- Vector transmission
  - Insect bite





Pandemics and Epidemics
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  - Fecal-oral
  - **Airborne**
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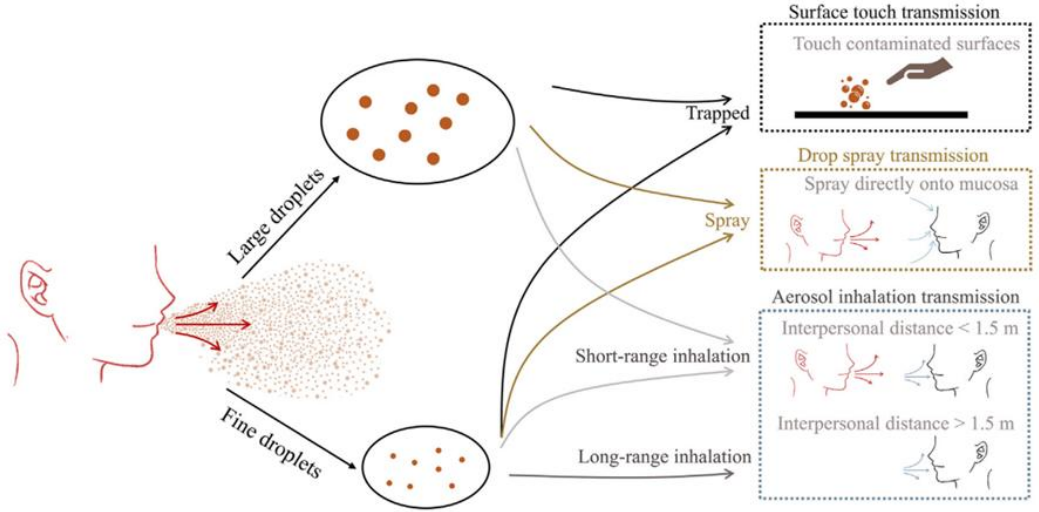


Fig 4. Droplets of various diameters caused different COVID-19 transmission routes (Modified from ref. [73]).

Pandemics and Epidemics

Risks and Health Impacts[5]

Risk is a combined effect of:

- Spark risk (where pandemic is likely to arise)
- Spread risk (how likely the disease is to diffuse)

Overall **health impacts** include:

- Widespread increase in morbidity and mortality
- Higher mortality impacts on LMICs
- Psychological damage

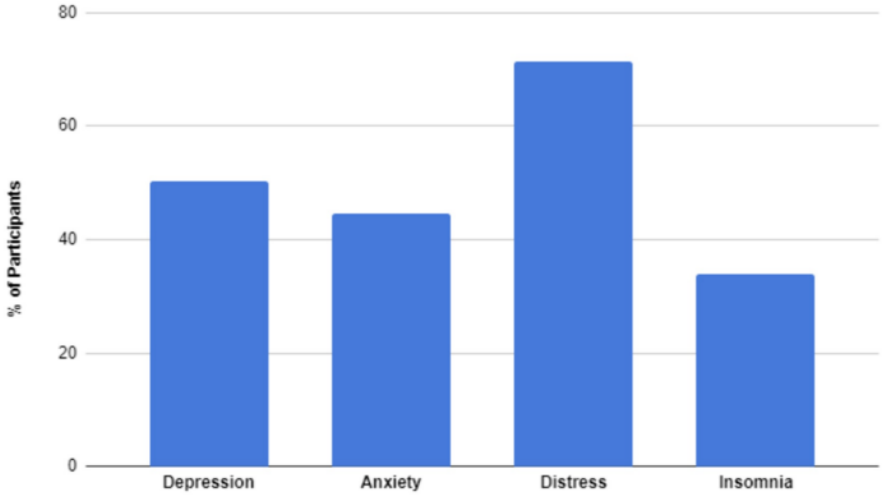
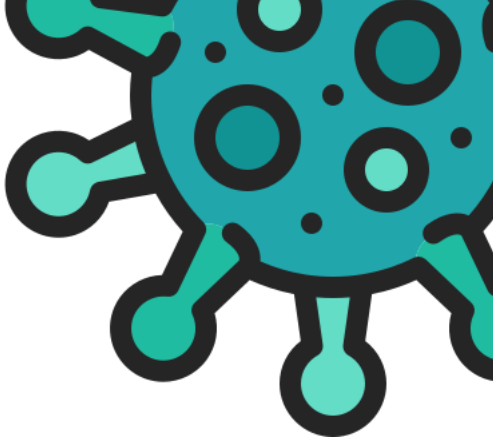


Figure - Percentages of healthcare workers showing mental symptoms during COVID-19 pandemic [7]



02 Context

Background
Lausanne M2 system

Characteristics
- Mostly underground
- Automatic metro line
- 36 millions passengers in 2024

Actual design
- Metal bar (stainless steel or aluminium)
- Textured seats
- Mechanical ventilation
- Narrow aisle

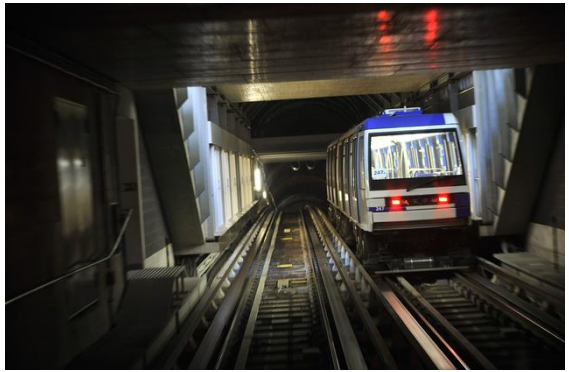
Background
Factor affecting transmission

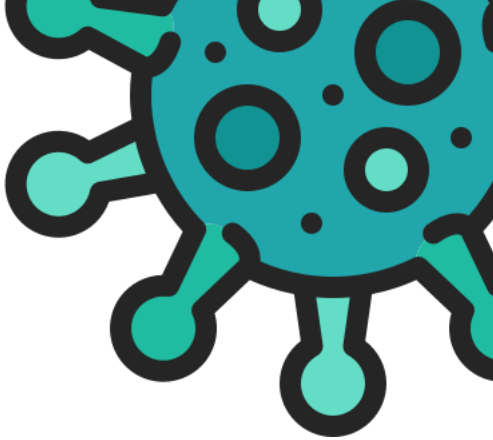
Aggravating factors

- High density during peak hour
- Proximity between passengers
- Enclosed underground environment
- Limited ventilation renewal
- Lot of contact with shared surfaces

Protective factors

- Automatic doors
- Regular maintenance (every day)
- Short average exposure duration (short travel – max 20 minutes)





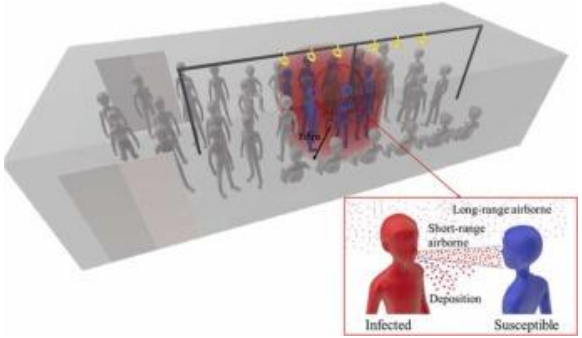
03 Risk assessment

Risk assessment

Passenger density

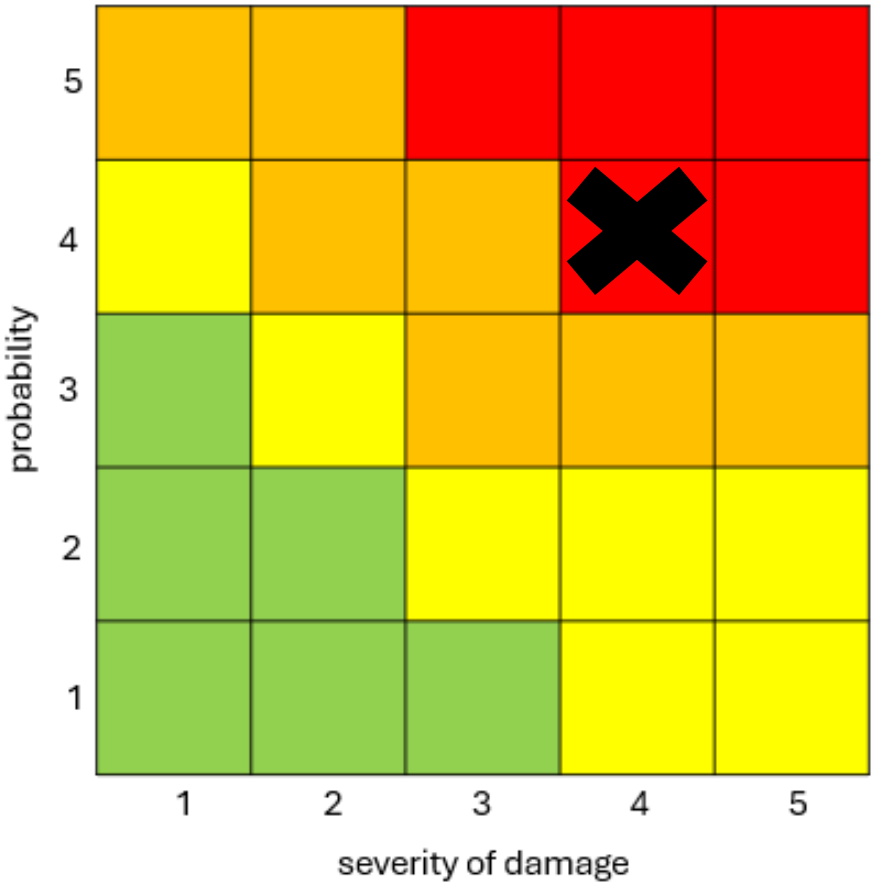
Criteria : density > 4 pers/m^2

- Increased short-range exposure



- Halving the density decreases infection risk by 20%-40% under same conditions [8]

SCORE = 4*4 = 16



Risk assessment
Ventilation

Criteria: **ACH < 3L/s/pers**

- Poor ventilation has been proved as one vital reason for cross-infection
- Probability of breathing infectious aerosols = 51% with bad ACH [9]

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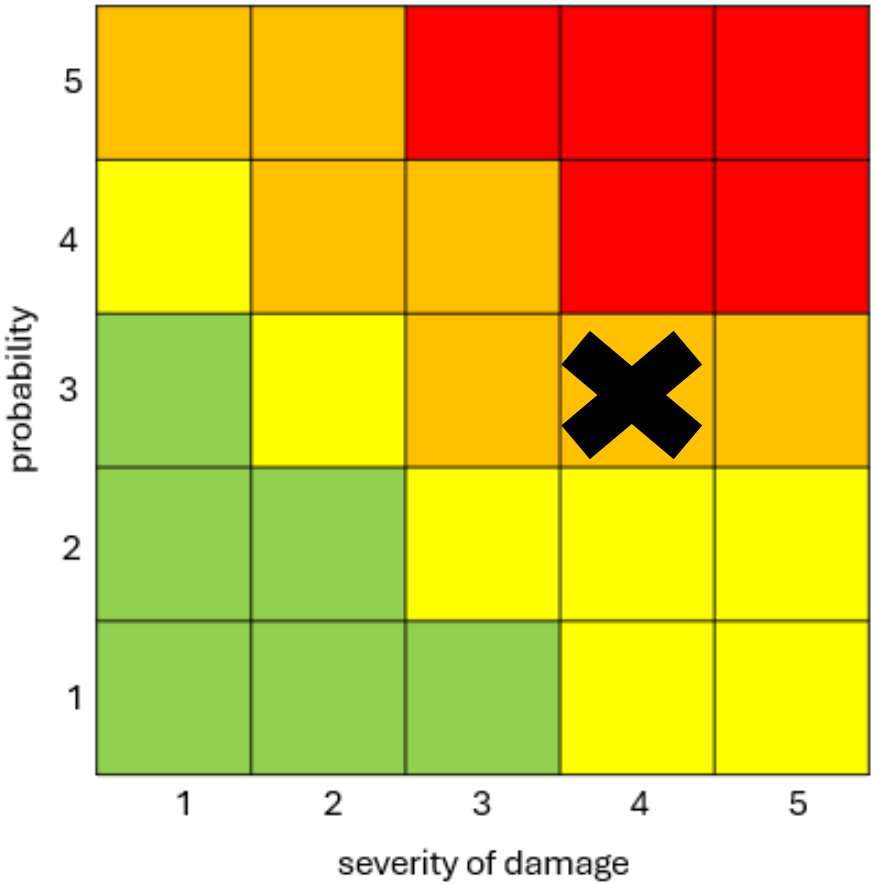
World

COVID cluster from Chinese bus trip offers more evidence of airborne transmission

September 2, 2020 / 7:20 AM EDT / AFP

SCORE = 4 * 3 =12



Risk assessment
Surface contact

Criteria: touch the bar at least once

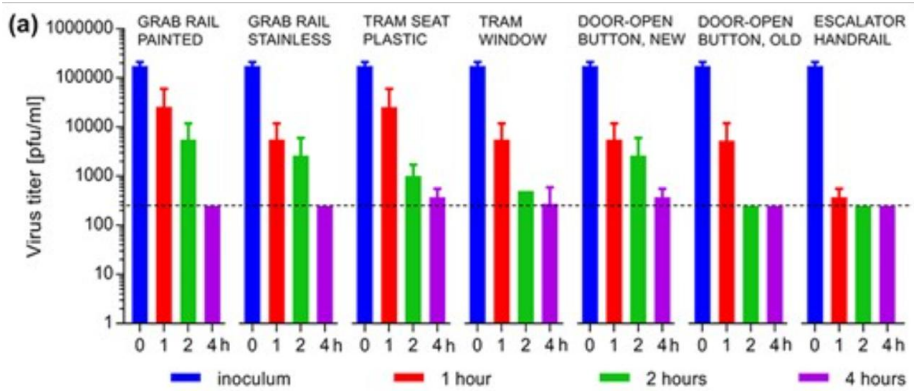
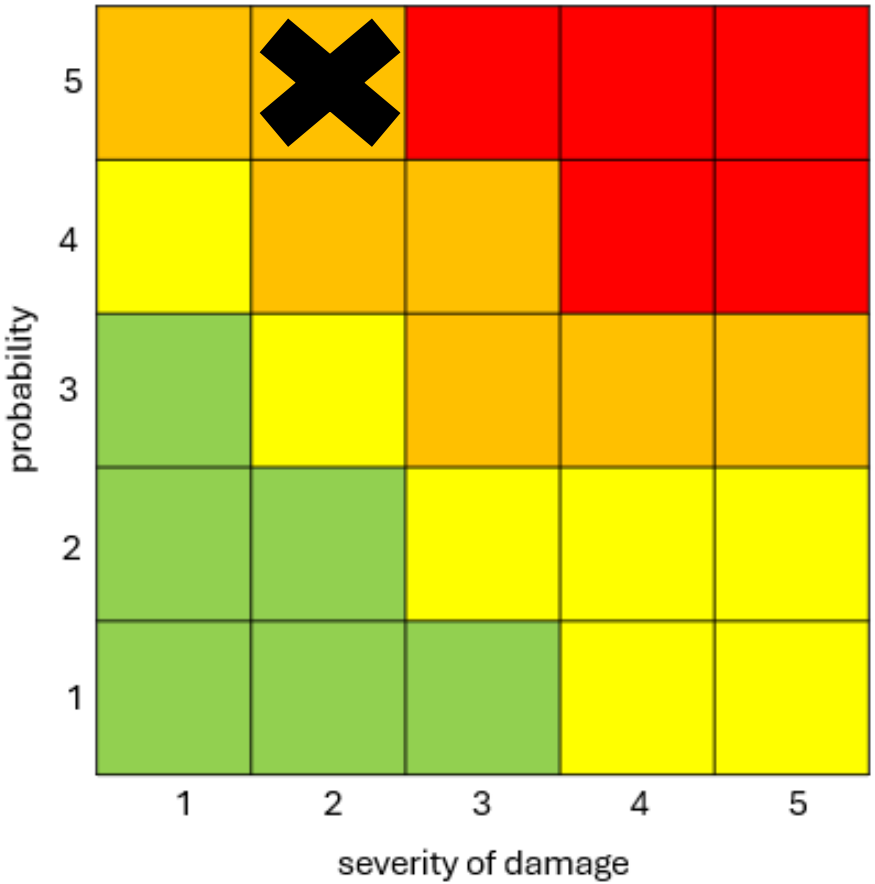
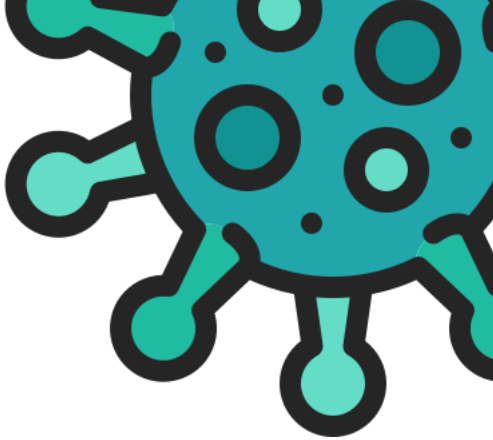


Fig. - The rate of decay of the SARS-CoV-2 virus on various exposed surfaces in public transport vehicles and stations in Prague

Of 482 samples, 10 were positive for viral RNA, but none were capable of replicating. [10]

SCORE = 2*5 = 10





04 Regulations

Swiss Legislation
Federal Act and Ordinance on Epidemics

- The Federal Act defines how to protect the population against transmissible diseases [12]
- The Federal Ordinance provides more practical informations on emergency plans, preventive measures and mandatory vaccinations.
- Additional ordinances linked to the specific characteristics and transmission ways of the disease [13]


Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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818.101 Federal Act of 28 September 2012 on Controlling Communicable Human Diseases (Epidemics Act, EpidA)

818.101

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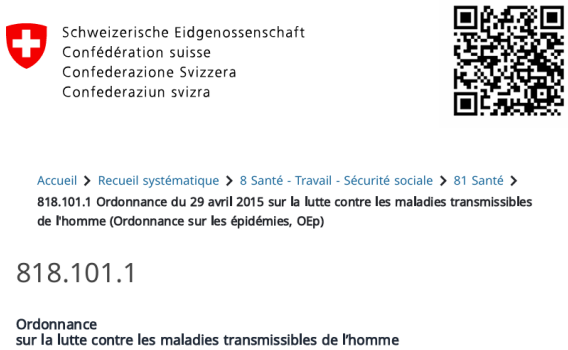
Federal Act
on Controlling Communicable Human Diseases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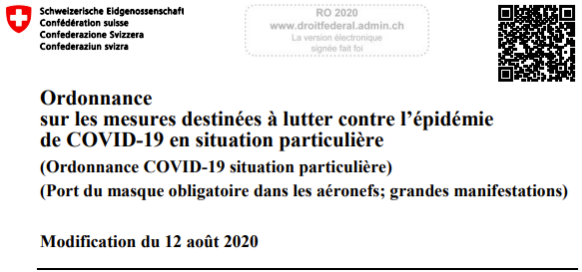
Accueil › Recueil systématique › 8 Santé - Travail - Sécurité sociale › 81 Santé ›
818.101.1 Ordonnance du 29 avril 2015 sur la lutte contre les maladies transmissibles de l'homme (Ordonnance sur les épidémies, OEp)

818.101.1

Ordonnance
sur la lutte contre les maladies transmissibles de l'homme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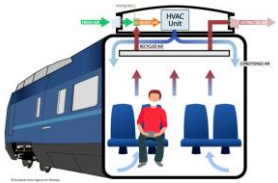
Ordonnance
sur les mesures destinées à lutter contre l'épidémie de COVID-19 en situation particulière
(Ordonnance COVID-19 situation particulière)
(Port du masque obligatoire dans les aéronefs; grandes manifestations)

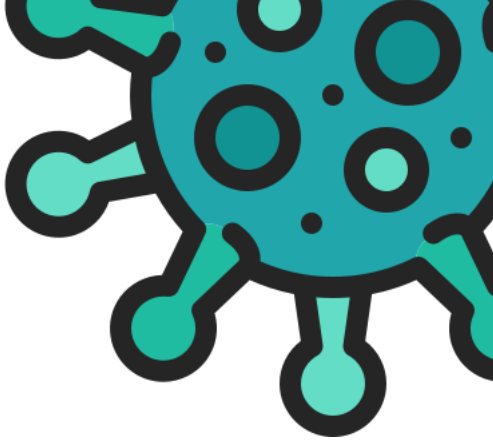
Modification du 12 août 2020

Global Legislation
Design recommendations – UITP and WHO

- UITP (International Association of Public transport), gives design and ventilation recommendations linked to IAQ.
- WHO published "**Supporting healthy urban transport and mobility in the context of COVID-19" [14]**

Actions for transport providers

Hygiene	Physical Distancing	Other
● Frequently disinfect facilities ● Hand-hygiene stations ● Barriers to separate drivers to passengers ● Contactless technology for door opening and ticketing	●  ● Provide incentives to reduce peak-time crowding	● Natural and mechanical ventilation of facilities with enhanced air filtration 

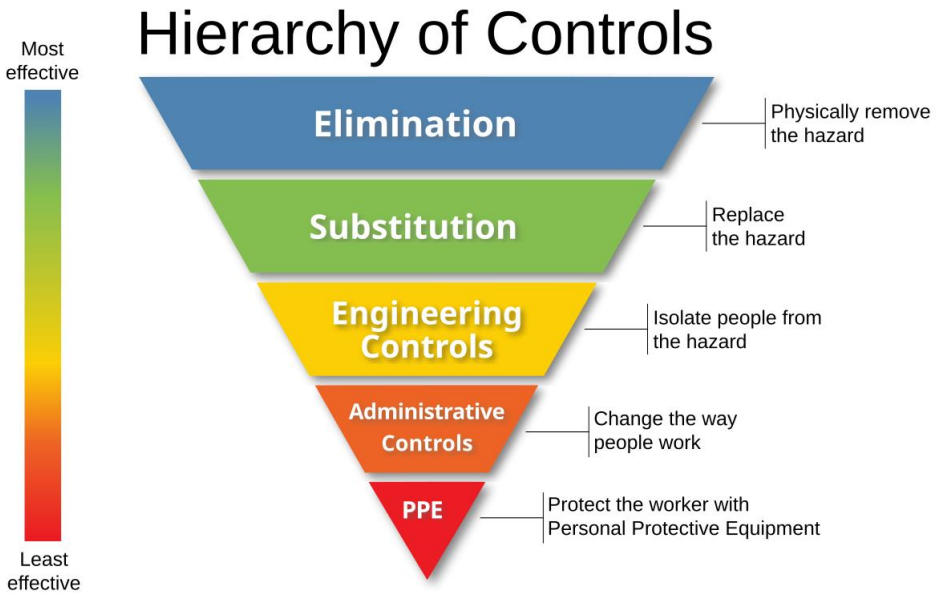


05
Solutions

STOP Hierarchy

Applied to determine, establish and implement protective measure for environments with high risk potential. It identifies a preferred order of actions to best control hazard exposure.

- **S**ubstitution – substitute materials / change process
- **T**echnical/engineering solutions – containment of the hazard
- **O**rganizational – training and awareness
- **P**ersonal Protective Equipments (PPE)



Applying STOP Hierarchy
S – Antimicrobial Surfaces

Goal: reduce the risk of fomite transmission

Idea:
- Use antimicrobial and antiviral surfaces, such as copper, for poles, handrails and seats

Expected Result
- A study (C. Williams et Al, 2024) assessed the antimicrobial resistance of copper in public transportations over a year [15]

➔ 42.7% CFU reduction in Toronto

➔ 39.1% CFU reduction in Vancouver

➔ No thickness reduction of copper during the 12-months period

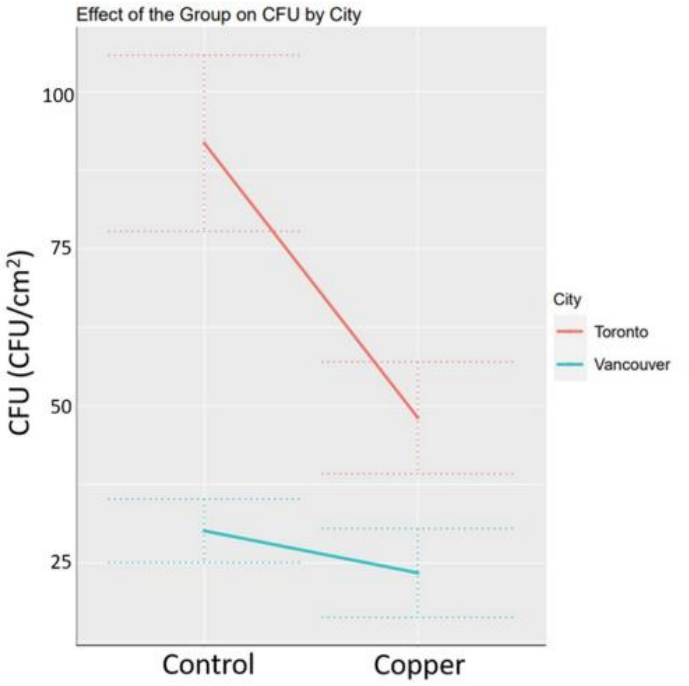


Figure - CFU measure in public transportations over control and copper surfaces

Applying STOP Hierarchy
T – Ventilation

Air dilution (HVAC):

- Introduce fresh air to dilute infectious aerosols
- 10%-15% fresh air → 70% viral load reduction → 37% lower infection risk [16]
- TARGET: ACH 12/h for optimal ventilation

Filtration (MERV/HEPA)

- Captures suspended viral particles

Strategic vent placement

- Supply vent: ceiling;
- Exhausts vent: floor

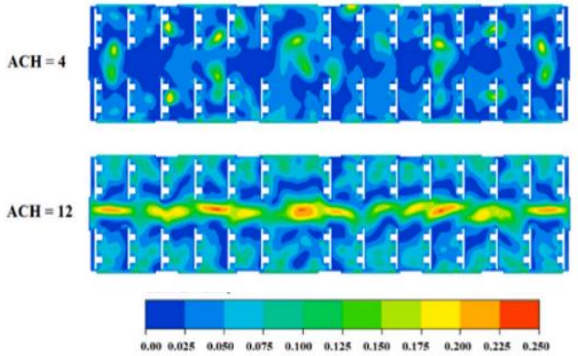


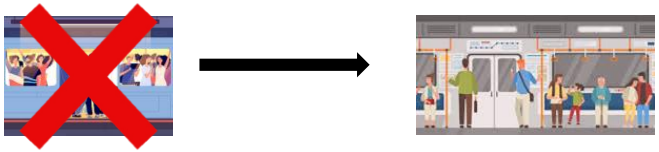
Fig. - Airflow velocity contours

Applying STOP Hierarchy
O – Organisational measures

Increase frequency of trains

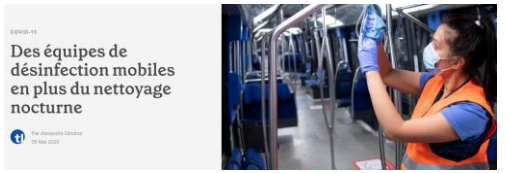
Goal: reduce crowding per carriage

More trains → fewer passengers → lower exposure



Enhanced cleaning

Goal: limit surface transmission
→ Surfaces disinfected regularly (bars, seat, handles)



Passenger flow management

Goal: reduce close contact

- Limitations on the number of passengers per carriage (max 50 person)
- Floor markings to maintain distance (1-2 m)

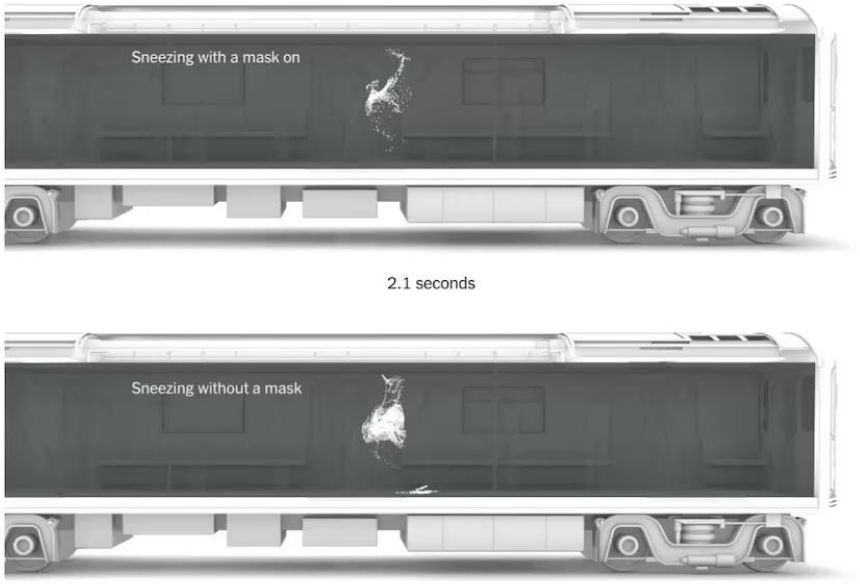
Communication

Goal: maintain safe passenger behavior

- Regular voice announcements
- Posters

Applying STOP Hierarchy
P – Personal protection

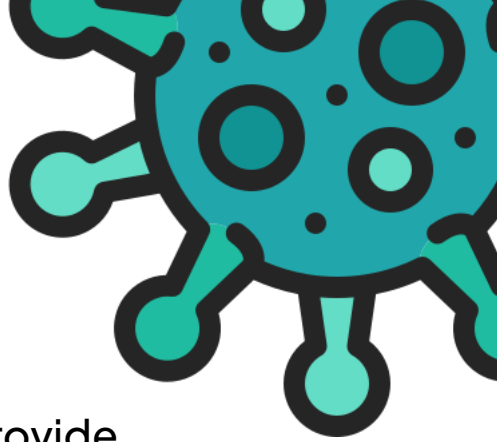
- Mask (surgical / FFP2)



- Hand sanitizer dispensers

PPE reduces risk but cannot replace ventilation or crowd control !

Conclusion



- Pandemic risk in the M2 metro is mainly driven by **high density**, **poor ventilation** and **airborne transmission**.

- While Swiss, WHO and UITP frameworks provide general guidance, there are no strict numerical limits requirements.

- The STOP hierarchy highlights the most effective mitigation strategies:

S: antimicrobial surface to reduce fomite risks
T: improved ventilation
O: increase train frequency, enhanced cleaning
P: masks

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