

An Infection Risk Calculation Tool for the Design of Better Indoor Environments

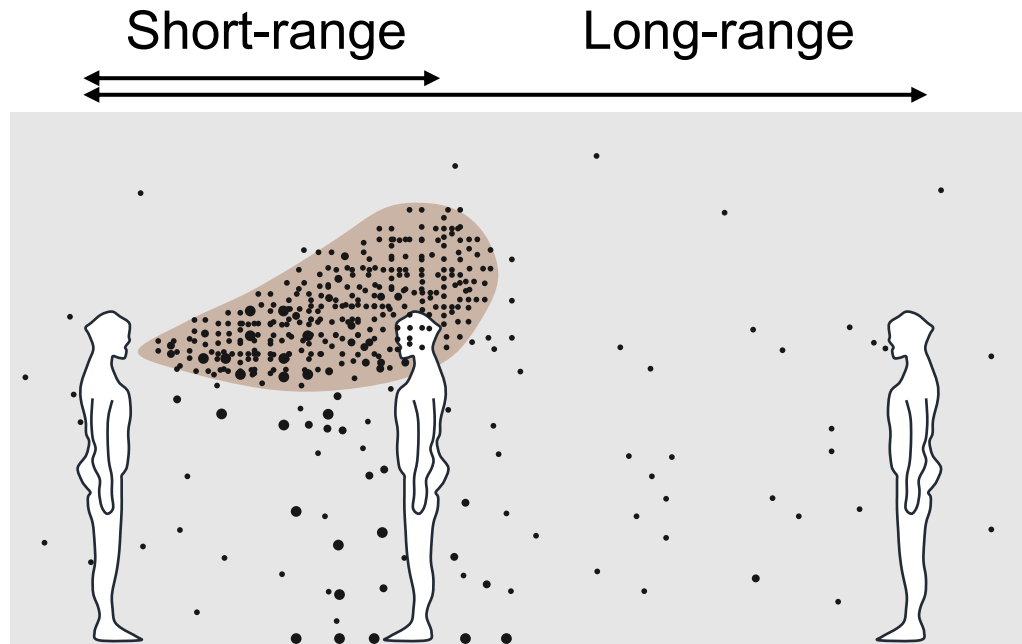
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Thomas Parkinson
CBE

Seema Bhangar
WeWork



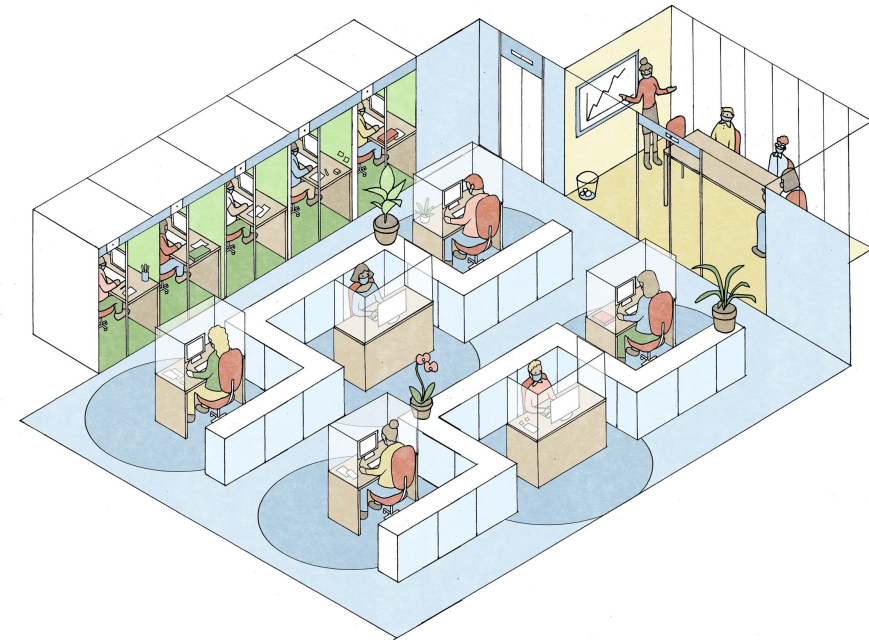
Building design and operation affect pathogen transmission

Airborne is one of the main routes of transmission of respiratory pathogens



Source: Li et al. (2020) *Indoor Air*

Better space and system design, and operation could decrease transmission



Source: The New Yorker

Mitigation actions should be implemented to decrease infection risk

Building-related

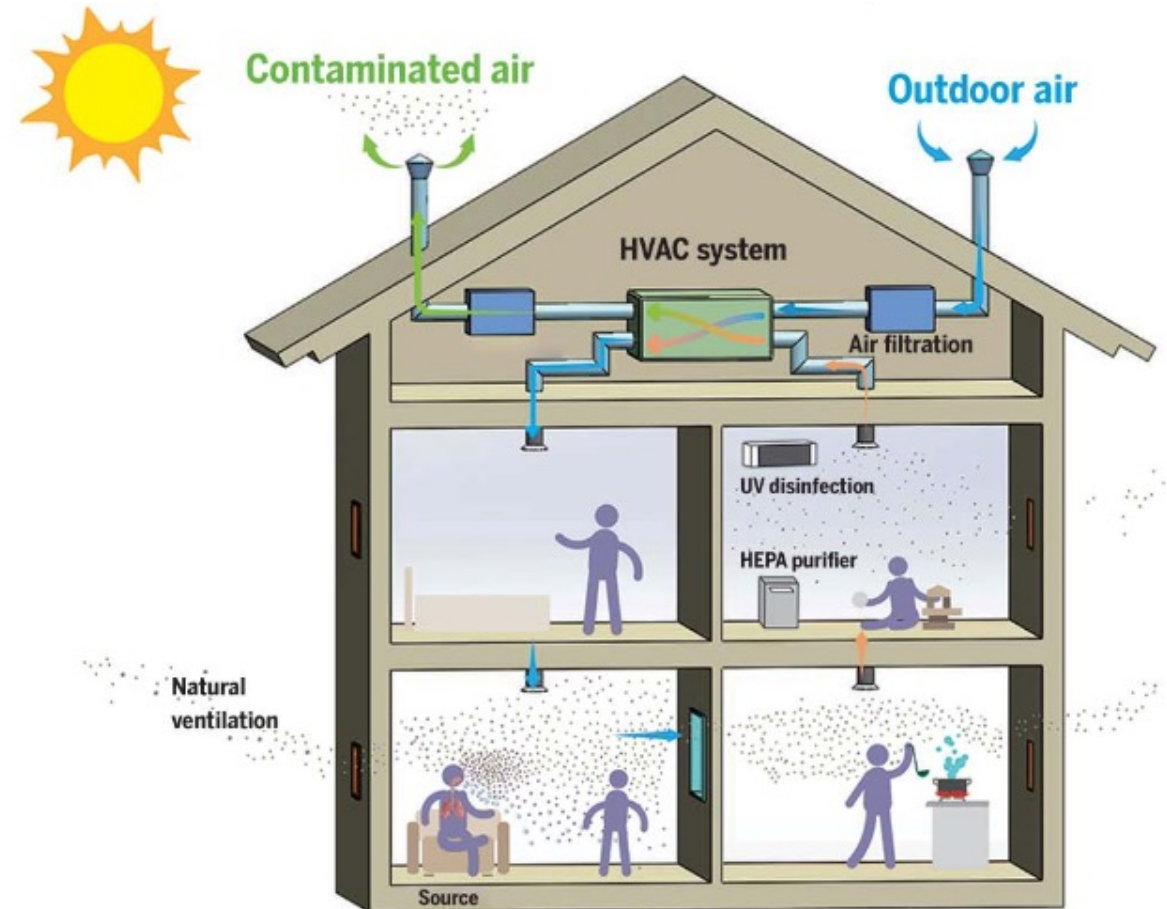
- Large room size
- High airtightness (infiltration)

Occupant-related

- Short occupied period
- Distancing
- Masking

System-related

- High ventilation rate
- Air filtration with a high-efficiency filter
- Air purifier



Source: Wang et al.

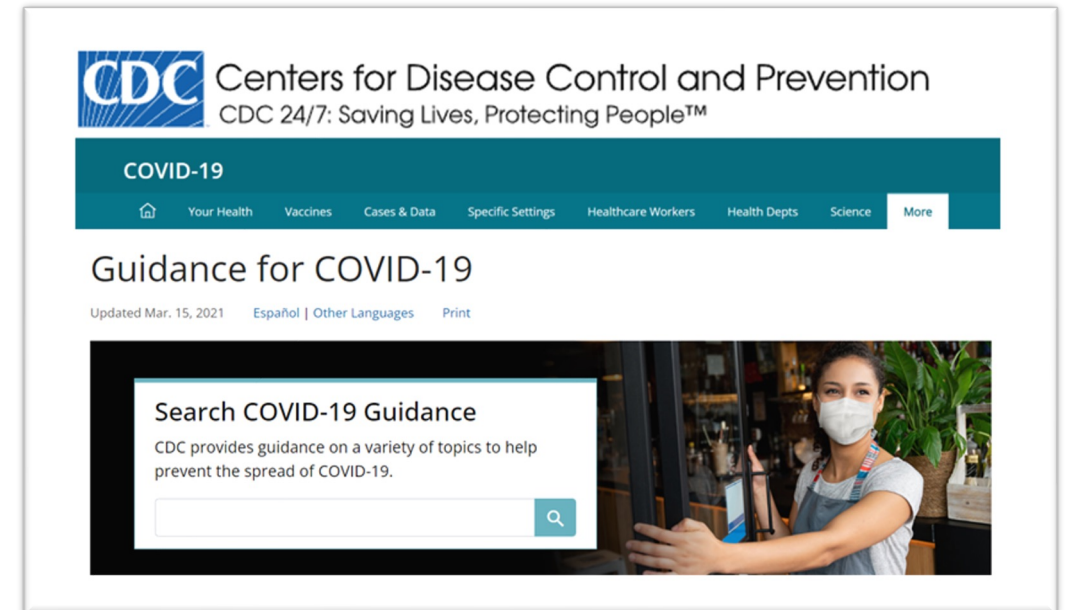
Wang et al, (2021) *Science*

Hard to use existing guidelines in designing infection-safe-environment

- Implementing mitigation actions should be considered in the building design phase
- However, the existing guidelines are hard-to-use for the stakeholders



The screenshot shows the EPA website's 'Indoor Air Quality (IAQ)' page. At the top, there is the EPA logo and a search bar. A navigation bar includes 'Environmental Topics', 'Laws & Regulations', 'Report a Violation', and 'About EPA'. The main heading is 'Indoor Air Quality (IAQ)' with a 'CONTACT US' link. A sidebar on the left lists 'Indoor Air Quality Home', 'Learn about Indoor Air Quality', 'IAQ by Building Type', and 'Network and Collaborate'. The main content area features the title 'Clean Air in Buildings Challenge' and the subtitle 'Guidance to Help Building Owners and Operators Improve Indoor Air Quality and Protect Public Health'.



The screenshot shows the CDC website's 'COVID-19' page. At the top, there is the CDC logo and the text 'Centers for Disease Control and Prevention CDC 24/7: Saving Lives, Protecting People™'. A navigation bar includes 'Your Health', 'Vaccines', 'Cases & Data', 'Specific Settings', 'Healthcare Workers', 'Health Depts', 'Science', and 'More'. The main heading is 'Guidance for COVID-19' with a sub-heading 'Updated Mar. 15, 2021' and links for 'Español | Other Languages' and 'Print'. A search box is present with the text 'Search COVID-19 Guidance' and 'CDC provides guidance on a variety of topics to help prevent the spread of COVID-19.' A background image shows a person wearing a face mask.



The screenshot shows the WHO website's 'Country & Technical Guidance - Coronavirus disease (COVID-19)' page. At the top, there is the WHO logo and the text 'World Health Organization'. A navigation bar includes 'Home', 'Health Topics', 'Countries', 'Newsroom', and 'Emergencies'. The main heading is 'Country & Technical Guidance - Coronavirus disease (COVID-19)'. A breadcrumb trail reads 'Home / Diseases / Coronavirus disease (COVID-19) / Technical guidance publications'.

Project overview

Objective

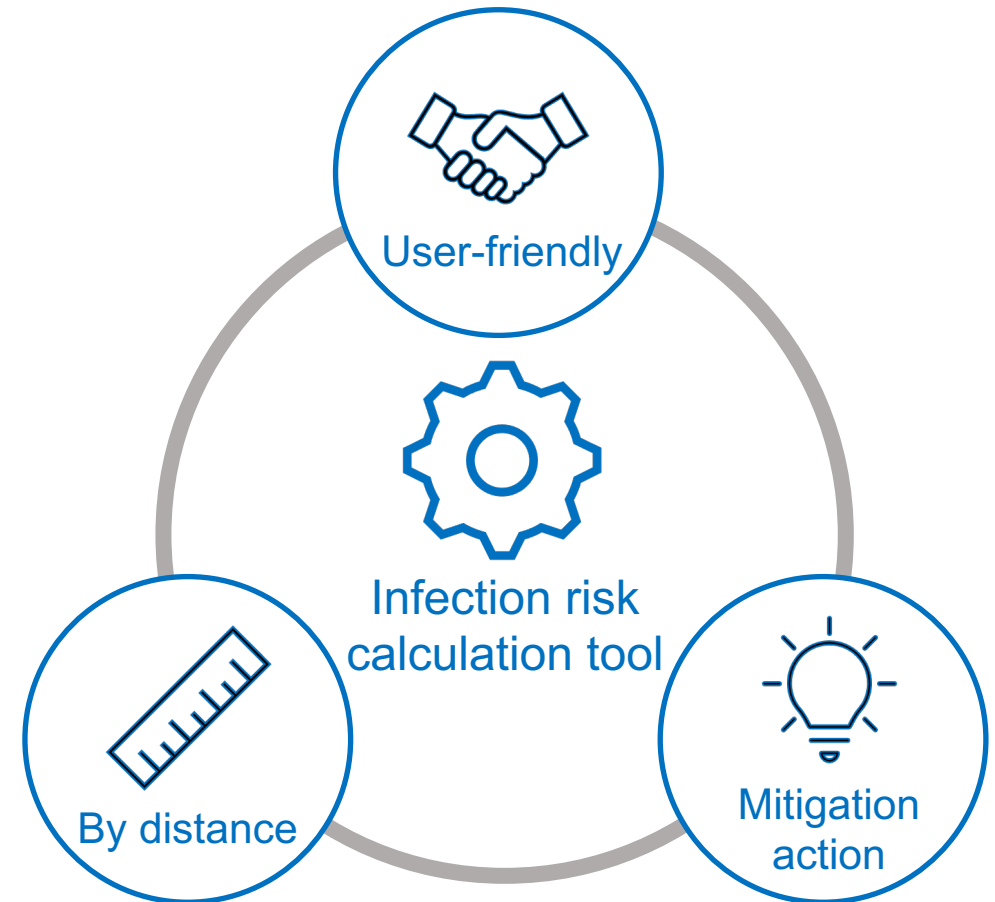
- Provide an early version of the tool to calculate airborne infection risk

Approach

- Develop a user-friendly tool that helps design building, system, and operation
- Calculate infection risk by distance
- Recommend mitigation action in building

Funding

- CBE industry consortium



Features that we need for a new tool vs. previous tools

Risk calculation by occupant distance

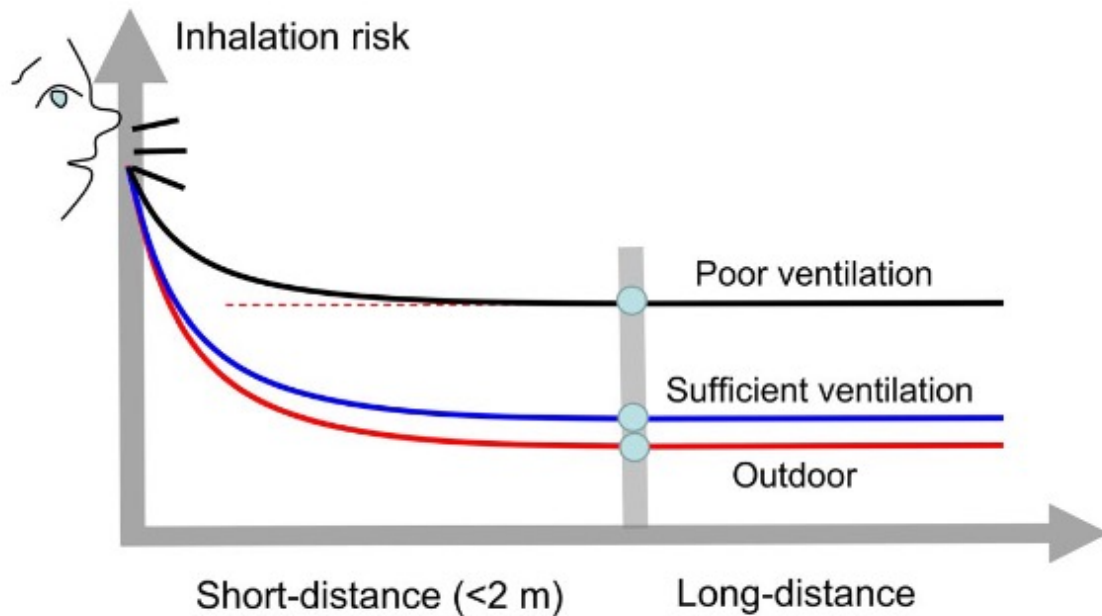
- A novel attempt to include calculation by distance

Recommended mitigation actions in a user-friendly interface

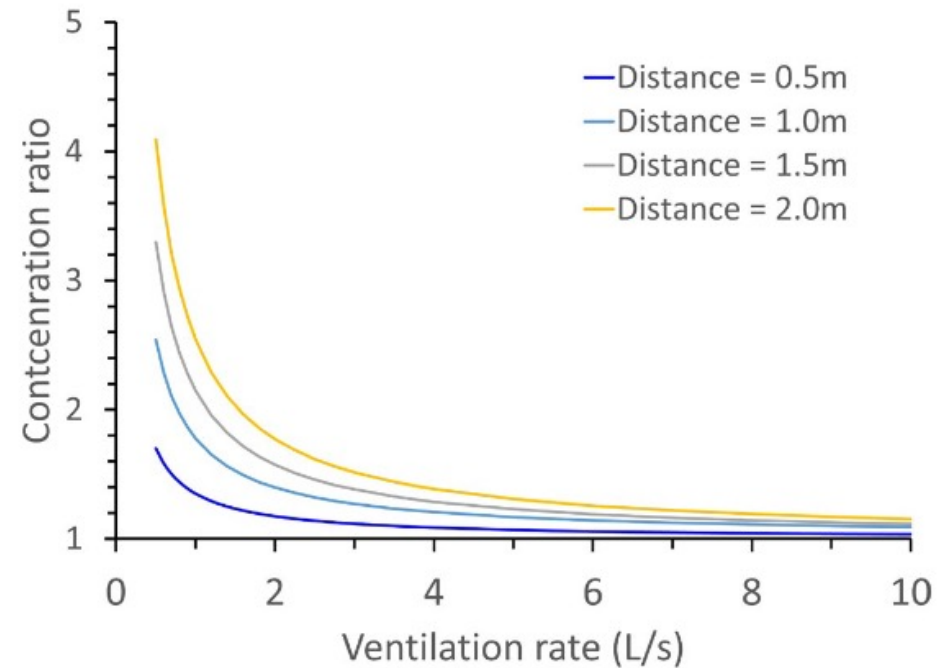
- Ventilation rate, HVAC filter type, air purifier, distancing, and mask requirements
- Quantifies how the effect of each mitigation action
- Recommends effective actions

Yuguo Li's finding: ventilation could decrease short-range transmission

Li found that the ventilation significantly affects the short-range airborne route



Distance should be considered when determining the ventilation rate

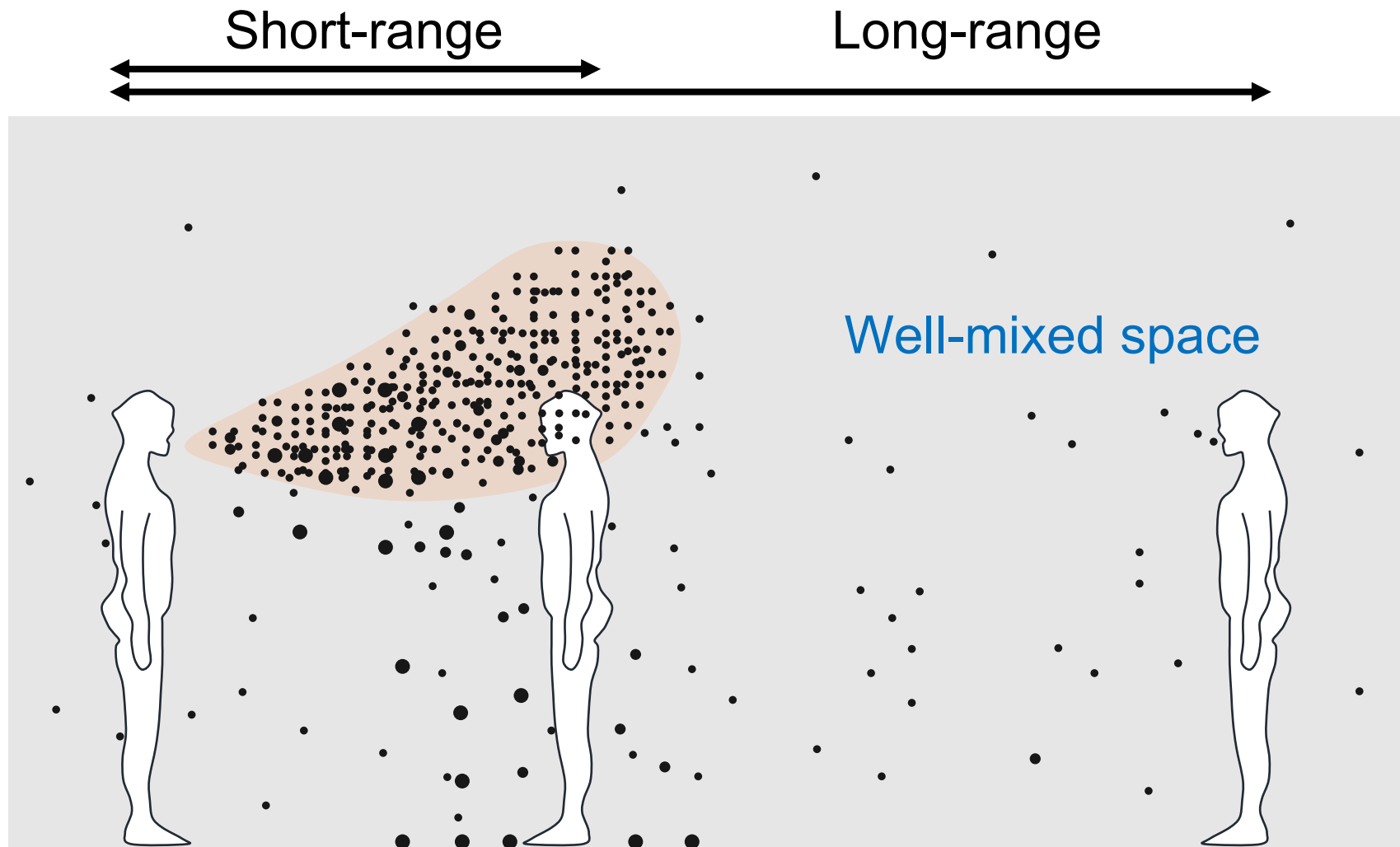


Source: Li et al. (2020) *Indoor Air*

Scientific models used in the tool

References	Model
Li et al. 2021, Indoor air	Mass-balance model for short- and long-range transmission zone
Buonanno et al. 2020, Environment International	Quanta concentration and infection risk in a well-mixed space
Wei and Li. 2015, Building and Environment	Buoyancy effect on turbulent jet model
Riley et al. 1978, American Journal of Epidemiology	Wells-Riley equation to calculate infection risk

Infection risk by distances: short- and long-range transmission



Source: Li et al. (2020) *Indoor Air*

Tool development process

What we did

- Reviewed existing tools and models
- Designed infection risk calculation model
- Designed a user-friendly interface
- Quantification how the effect of each mitigation action
- Recommendation of mitigation action



Where are we going

- Upgrade as a long-lasting tool
- Develop the tool used by real practitioners designing buildings
- Preparation for the next pandemic or flu season

We are presenting an early-version of the tool to collect feedback

Feedback to upgrade the tool

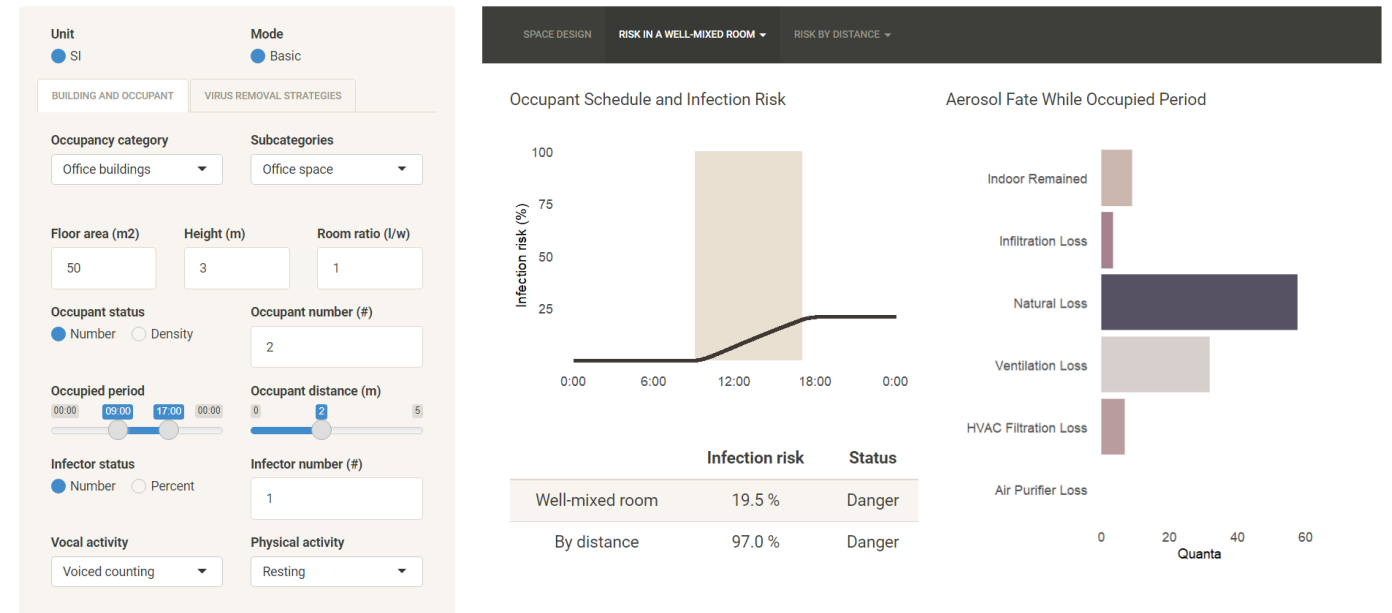
- Contact us to give feedback
- We will consider your valuable comments to create a better version of the tool

Technical advisory committee

- After the CBE meeting, we will organize a technical advisory committee for the tool
- Please e-mail us if you are interested

Infection Safe Environment Design Tool

Center for Built Environment | Chai Yoon Um, Stefano Schiavon, Thomas Parkinson, Seema Bhangar



Link to the Shiny app:
http://tiny.cc/infection_risk



Example:

Shared closed office space



Source: Office suites

Input: closed office space, 500 ft², 6 occupants, 8 hours

BUILDING AND OCCUPANT | **VIRUS REMOVAL STRATEGIES**

Occupancy category: Office buildings
Subcategories: Office space

Floor area (ft²): 500
Height (ft): 10
Room ratio (l/w): 1.5

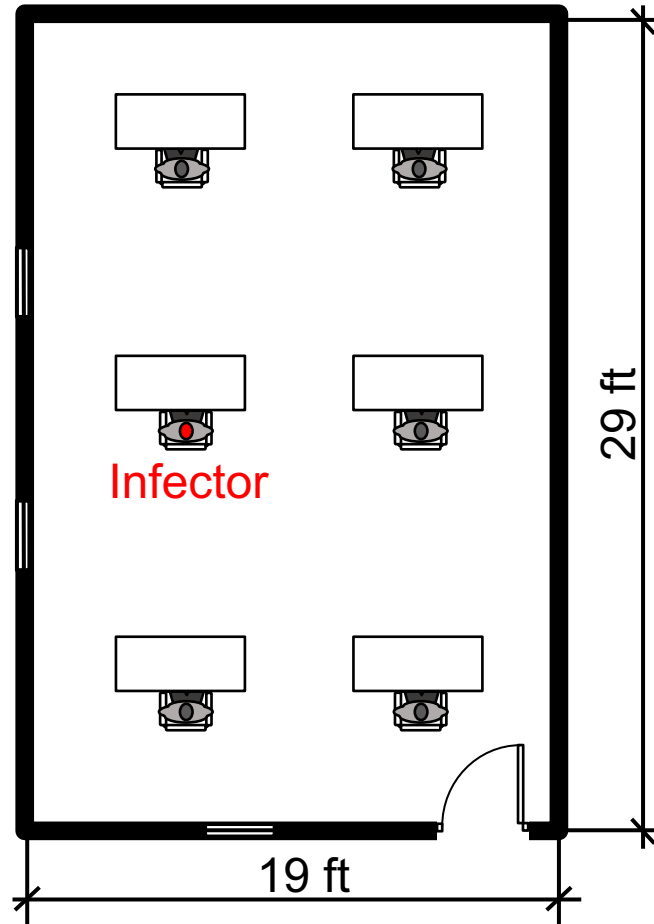
Occupant status: Number Density
Occupant number (#): 6

Occupied period: 00:00 - 09:00 - 17:00 - 00:00
Occupant distance (ft): 0 - 10 - 15

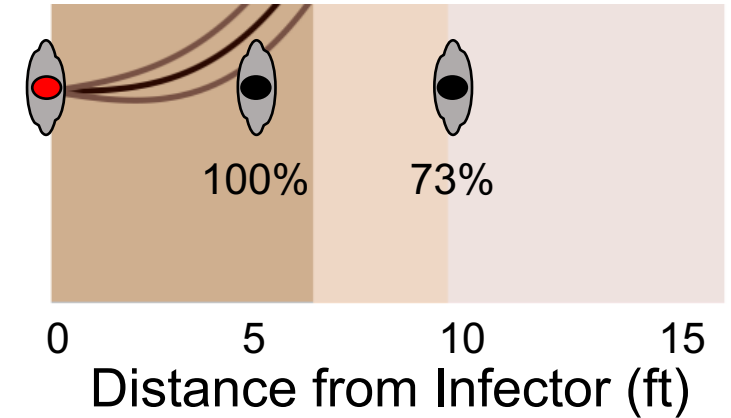
Infectior status: Number Percent
Infectior number (#): 1

Vocal activity: Speaking
Physical activity: Standing

Space design



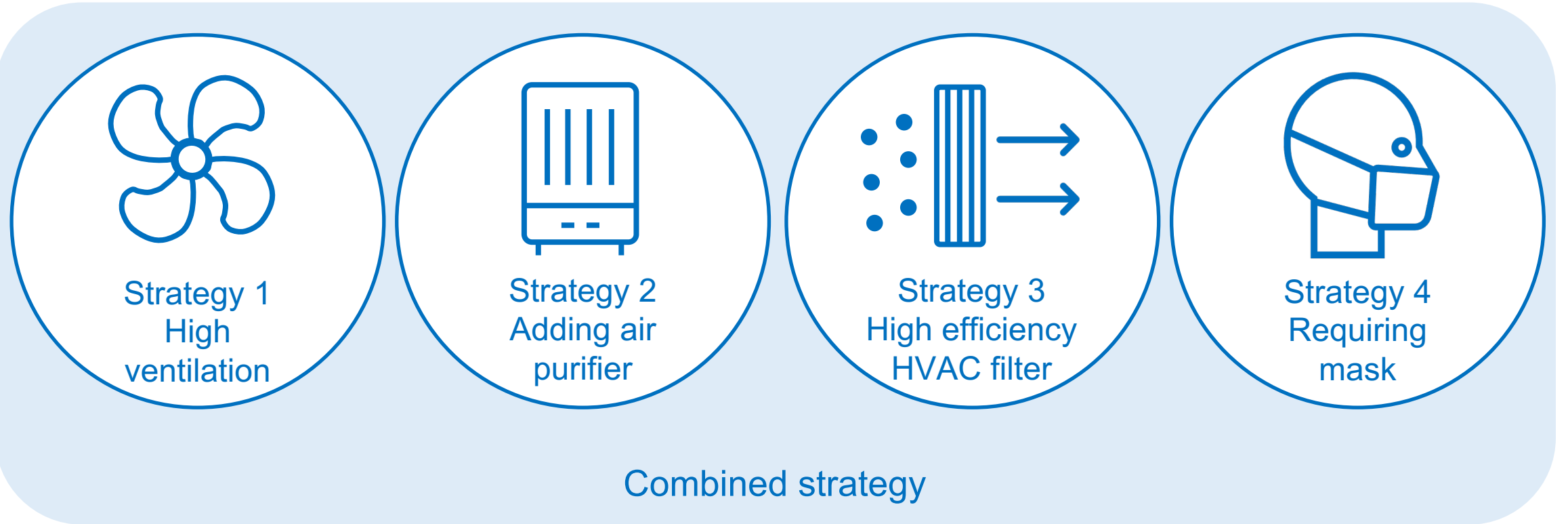
Distance design



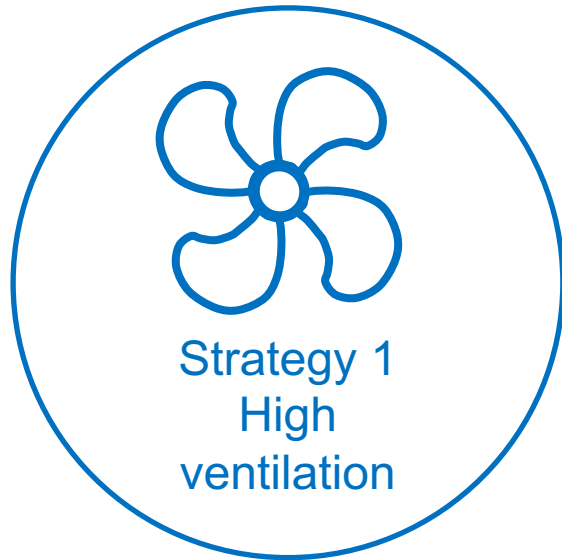
STATUS: DANGER

Infection risk: 73%

Four strategies to decrease infection risk

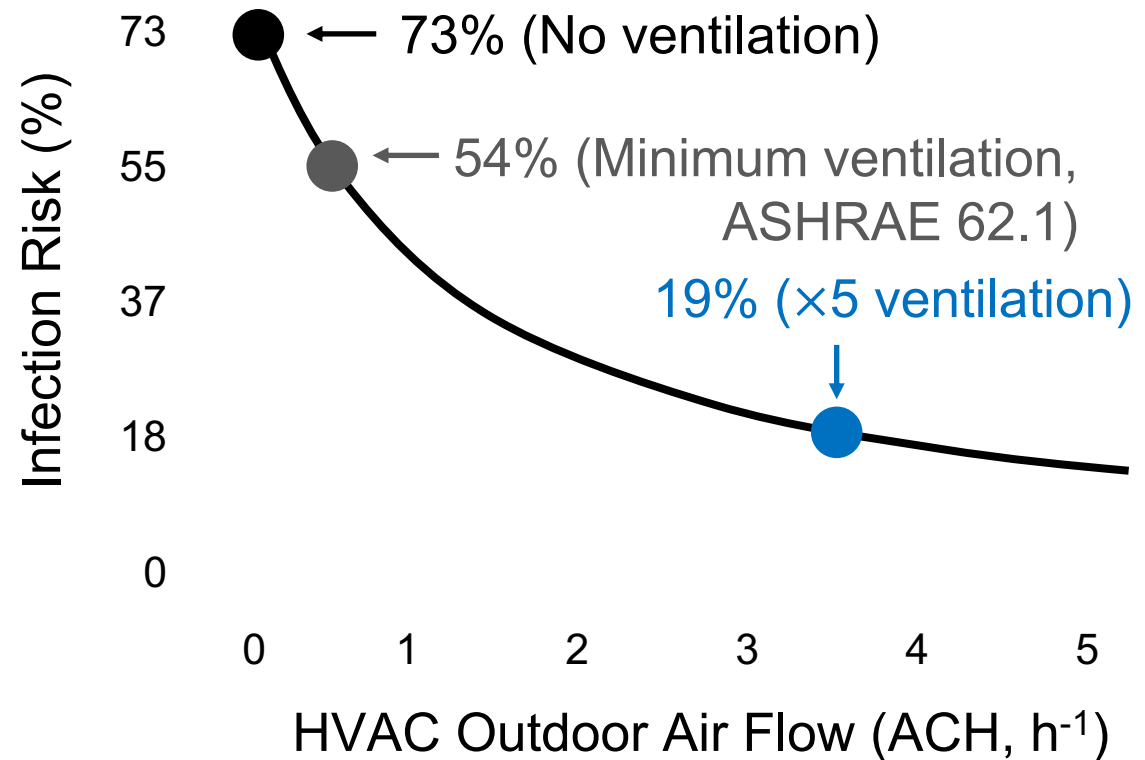


Strategy 1: High ventilation has a large effect



STATUS: DANGER

Infection risk
73% → 19%



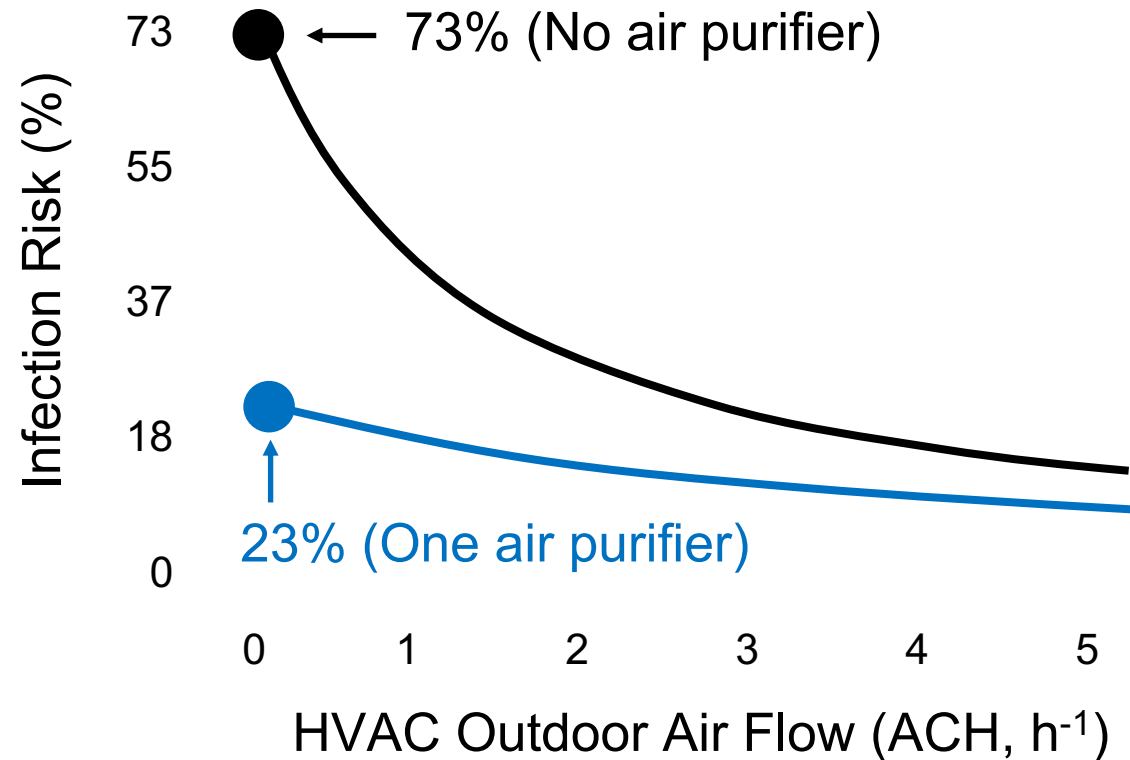
- Five times high ventilation rate of minimum ventilation from ASHRAE 62.1: 307 cfm (3.7 ACH)

Strategy 2: Adding an air purifier has a large effect



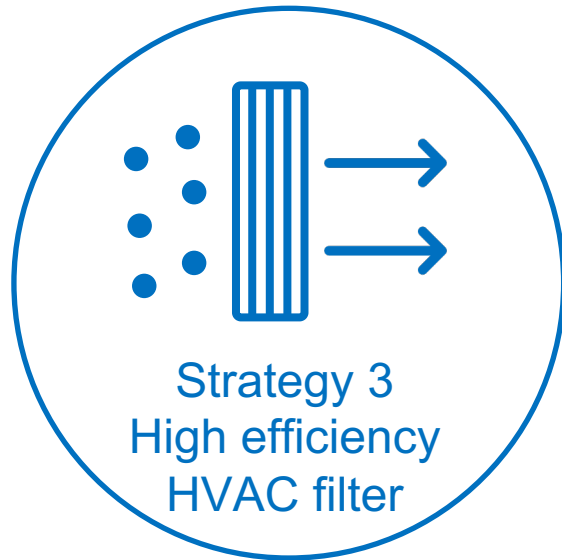
STATUS: DANGER

Infection risk
73% → 23%



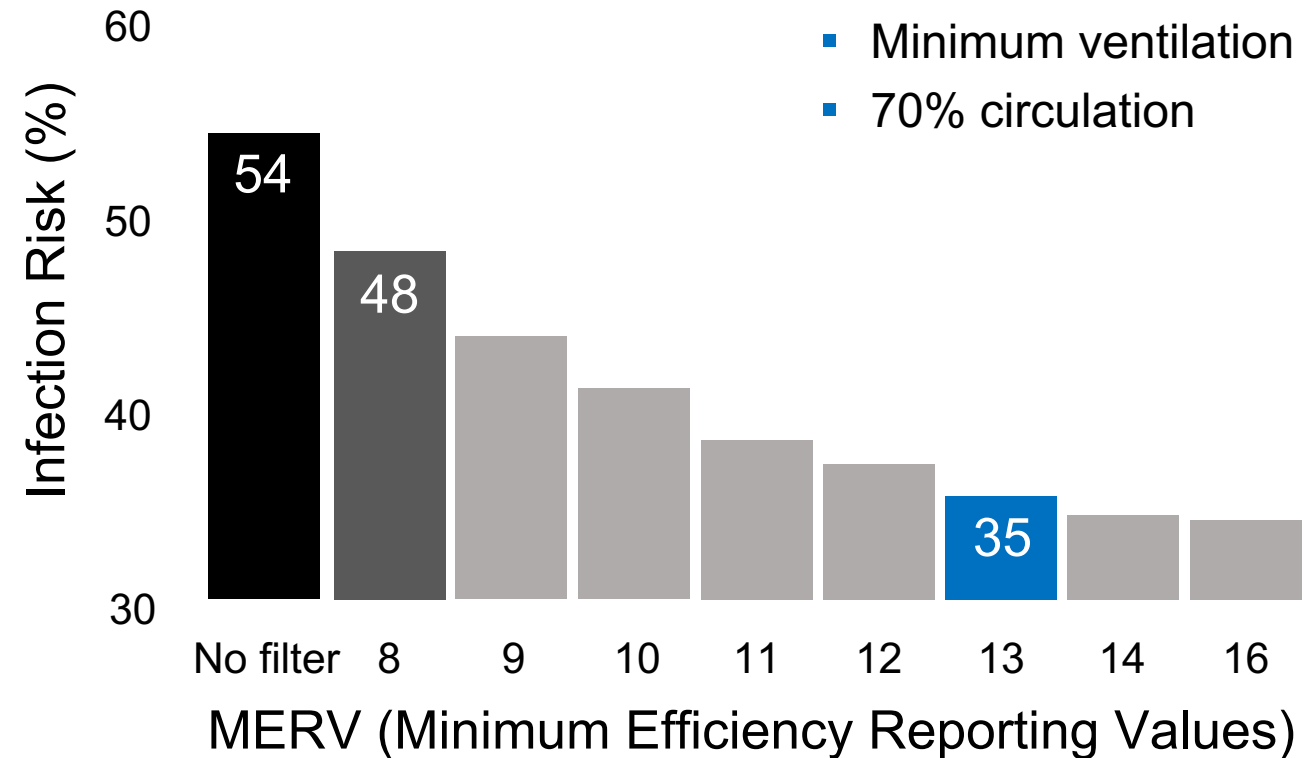
- One air purifier has been added

Strategy 3: High efficiency HVAC filter (MERV 13) is effective



STATUS: DANGER

Infection risk
73% → 35%
(Minimum ventilation)



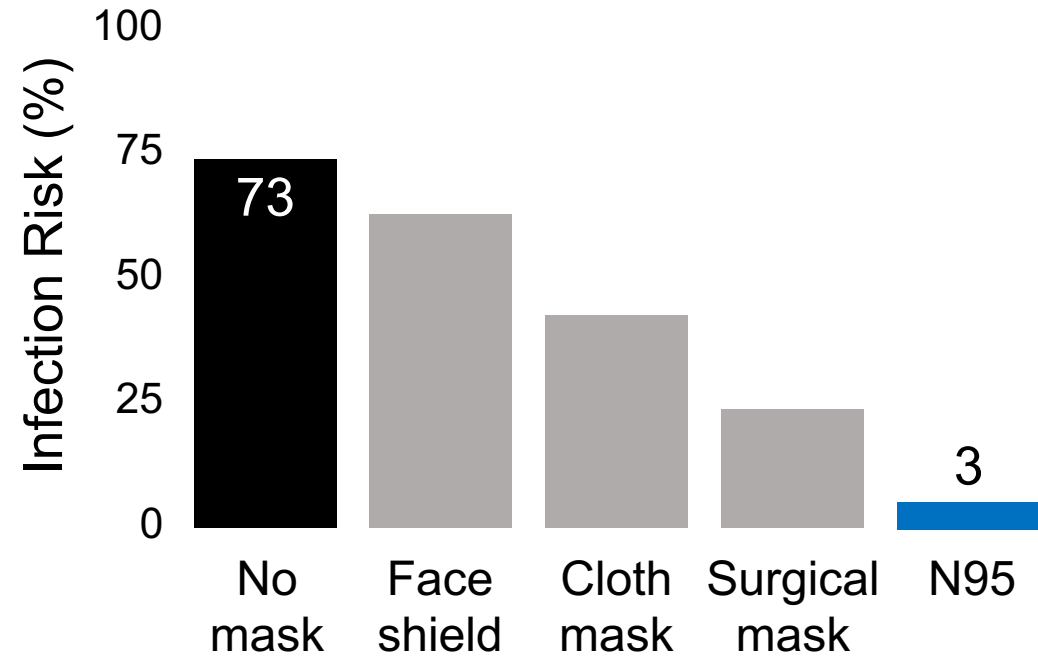
- HVAC filter type has changed from MERV 8 to MERV 13

Strategy 4: Masking has a large effect



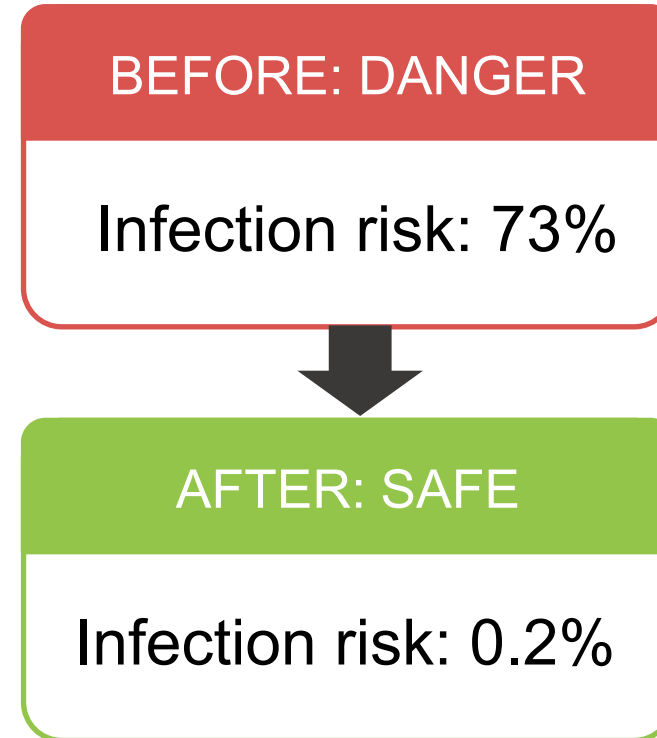
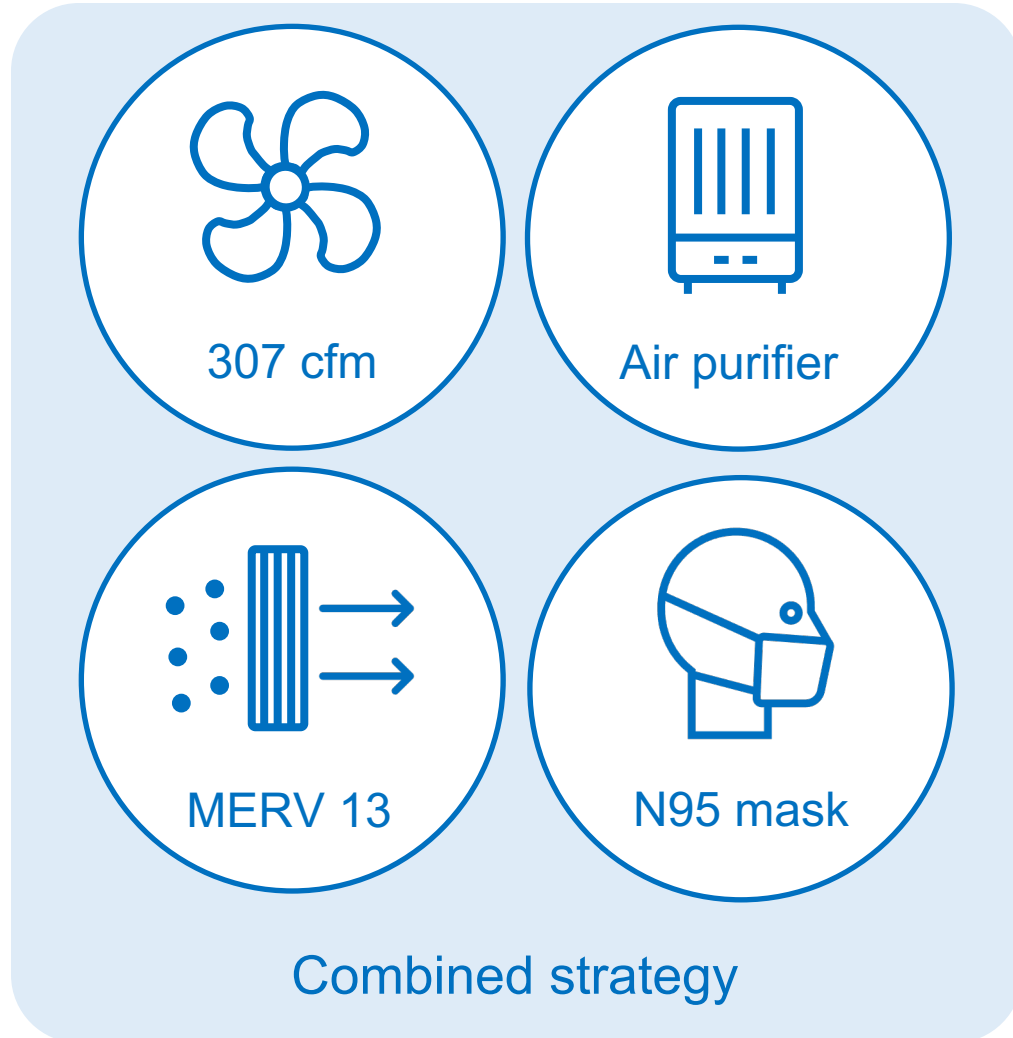
STATUS: DANGER

Infection risk
73% → 3%



- N95 mask has been applied to the occupants

Combining four strategies will decrease infection risk to 0.2%



Limitations

The current tool does not consider...

- Different types of air distribution
- Ultraviolet (UV) disinfection
- Natural ventilation
- Vaccination status
- Different types of viruses
- Infection prevalence
- Standards, codified conditions
- Energy consumption
- Cost and benefit analysis

Accuracy of infection risk calculation

- Limited knowledge of quanta emission rate
- Validation is needed



Source: Faculty focus

Next steps

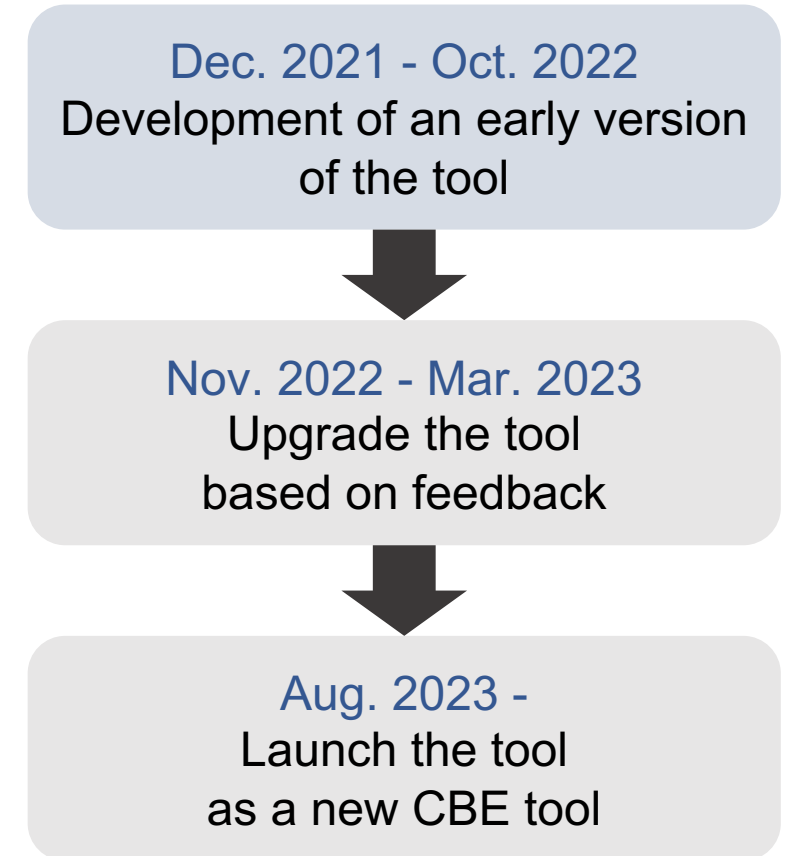
Overcome limitations

Upgrade the tool based on feedback

- Include feedback from users after their trial use
- Organize a technical advisory committee

Develop the tool as a new CBE tool

- Launch the tool to be broadly used by various practitioners



Q&A

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Feel free to e-mail us if you are willing to become a member of the technical advisory group

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Unit: SI Mode: Basic

BUILDING AND OCCUPANT VIRUS REMOVAL STRATEGIES

Occupancy category: Office buildings Subcategories: Office space

Floor area (m2): 50 Height (m): 3 Room ratio (l/w): 1

Occupant status: Number Occupant number (#): 2

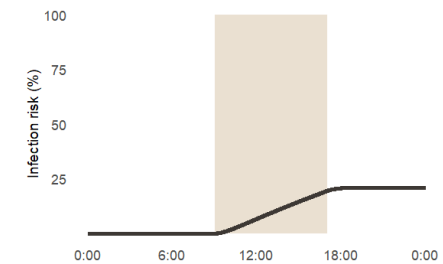
Occupied period: 09:00 - 17:00 Occupant distance (m): 2

Infector status: Number Infector number (#): 1

Vocal activity: Voiced counting Physical activity: Resting

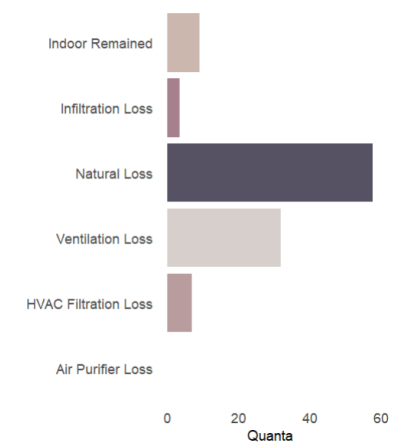
SPACE DESIGN RISK IN A WELL-MIXED ROOM RISK BY DISTANCE

Occupant Schedule and Infection Risk



	Infection risk	Status
Well-mixed room	19.5 %	Danger
By distance	97.0 %	Danger

Aerosol Fate While Occupied Period



Link to the Shiny app:
http://tiny.cc/infection_risk

