cantene

Presentazione Cantene ™

PREDICTIVE
MODELS FOR
ENGINEERING

The use of numerical simulations to plan a mass event during pandemia

FEMTC 2022, Brno

About us

Cantene is a Politecnico di Torino spin-off (Energy Dept.) specialized in numerical modelling & simulations.

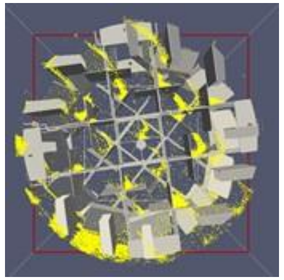
- 1D and CFD analysis, multiscale technique, tunnel ventilation system design
- Multiphysics and dem analysis
- risk analysis
- crowd modeling

Infrastructure

Buildings

events

factory



Presentation Outline

- The event
- The aim of the analyses
- The performances to monitor
- Results
- Conclusions

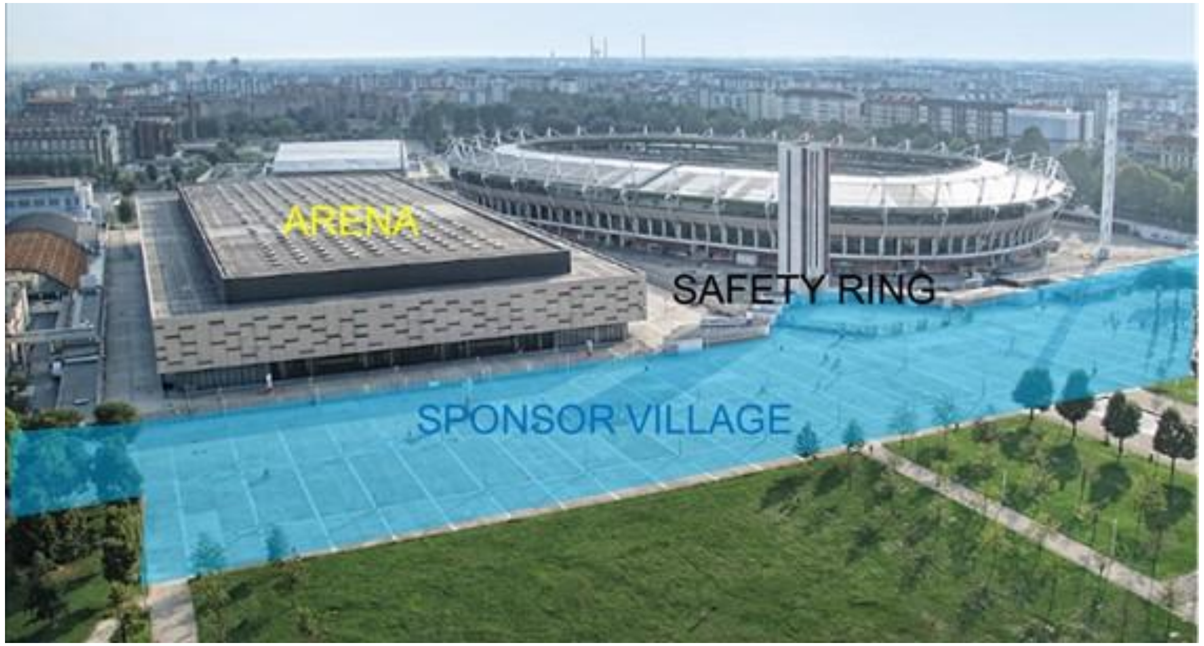
Nitto ATP finals

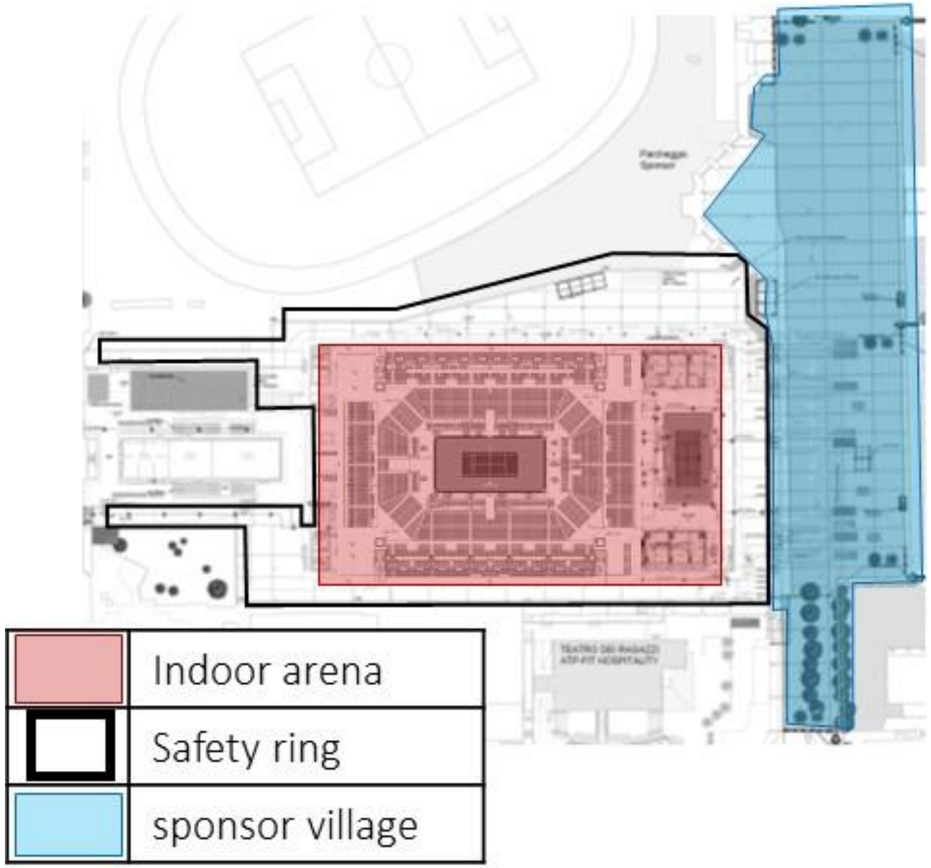
- Nitto ATP finals took place at the Pala Alpitour in Turin, Italy
- The program consists of 15 events (2 sessions per day) from the 13th to the 21st of November of 2021

More than 90000 spectators in the week

The site

- The indoor Arena
- The safety ring, around the arena
- the outdoor sponsors village





Why a performance-based approach

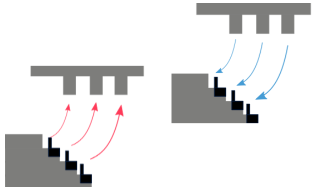
- ☐ Pala Alpitour is a site designed to host sport events with a large number of spectators.
  - ▪ The means of egress was verified to guarantee evacuation in emergency conditions in less than 8 minutes (Green Guide);
  - ▪ Spaces (corridors, gangways) were designed to guarantee people can move during the egress and ingress phase without bottlenecks in a comfortable way.
- ☐ WHY a performance-based approach?
  - ▪ **Covid context**:
    - ✓ Italian regulations stated: FFP2 mask and 1 m distance were mandatory for indoor events. These constraints would have implied a strong reduction of users, load factor (50%, 75%). Italian Committee asked a quantitative view of the risk exposure to Covid;
    - ✓ FIT (Federazione Italiana Tennis) wanted to increase the number of spectators. FIT objective was to obtain from the simulation management suggestions;
    - ✓ The safety plan had to demonstrate people are not exposed to Covid risks and that ingress and egress phases can take place without bottleneck, long queue, delay etc;

The Covid risk exposition during the ingress and egress phases in ordinary conditions had to be explored (queue, high density aeras, social distancing, the influence of the mechanical ventilation);

The aim of the analysis

- ☐ **Support the formulation of the safety plan**
  - Management goals: keep under control the ingress time, evaluate the number of stewards/gate;
  - Safety: to evaluate the risk exposition to Covid (the exposure and queue time, the deposition of aerosol and the aerosol concentration, dilution/air-exchanges)

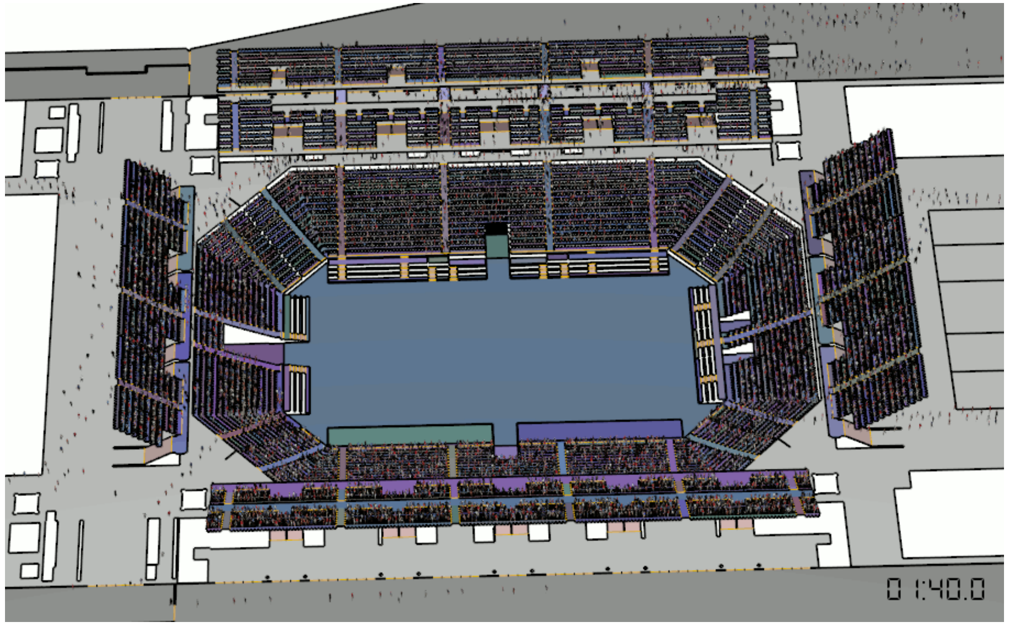
- ☐ **Produce many scenarios to explore what changes in function of:**
  - Load factor: 50%, 75%, 100% (50% corresponds to have 1m of social distance when people is seated);
  - Time /person during the ingress phase necessary to check the vaccine certification, tickets: 20s, 25s;
  - number of steward per gate: 2,3,4;
  - The air flow rate and the logic of the ventilation system.



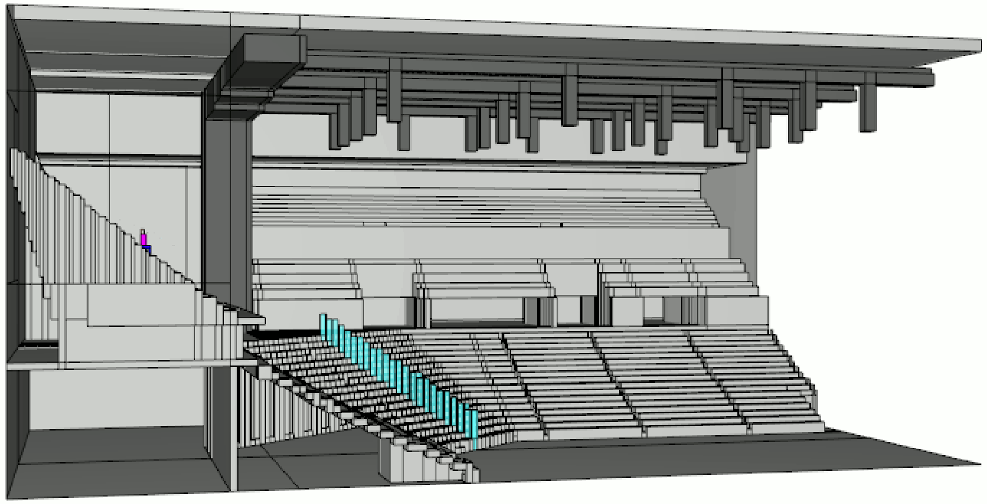
The models

PREDICTIVE
MODELS FOR
ENGINEERING

Agent based analysis



CFD analysis



Performance to monitor

A huge number of simulation have been developed considering the entire domain <u>using Pathfinder</u> in function of:

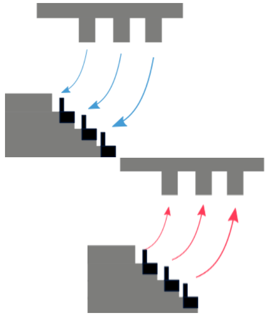
- Load factor
- gates

Agent based analysis

- **Ingress time**.
- **Queue time**.
- **Egress time** (normal operation).
- **Evacuation time** (emergency operation).
- **Exposure (spatial)**: Number of people inside the 1m radius of social distancing.

Simulations have been developed considering the entire arena <u>using FDS</u> considering:

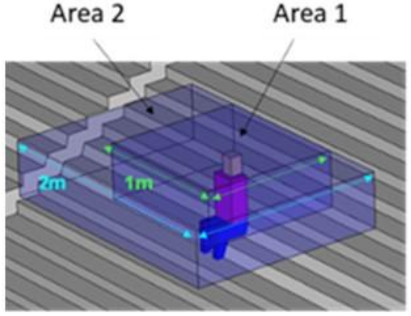
- Louver position
- Ventilation system direction
- HVAC capacity



CFD analysis

Volatile fraction

- **Air velocity vector**
- **Aerosol deposition**, on the surfaces.
- **Concentration** in 2 different control volumes



Control volume where the performances are monitored

Goals/thresholds

- ❑ **Management goals**
  - Ingress time < 2h
  - Number of stewards: to determine by the simulations

- ❑ **Risk of Covid exposure**
  - Pedestrian analysis
    - Exposure time stats < 15min (https://www.cdc.gov/coronavirus/2019-ncov/your-health/risks-exposure.html)
    - Queue time stats (comparative evaluation)
  - CFD analysis
    - Behavior of the plume of aerosol close to a single person through air velocity vectors (qualitative)
    - Aerosol deposition
    - Aerosol concentration in a control volume (close to a single person)

PREDICTIVE
MODELS FOR
ENGINEERING

PEDESTRIAN ANALYSIS

Pedestrian analysis: people characterization

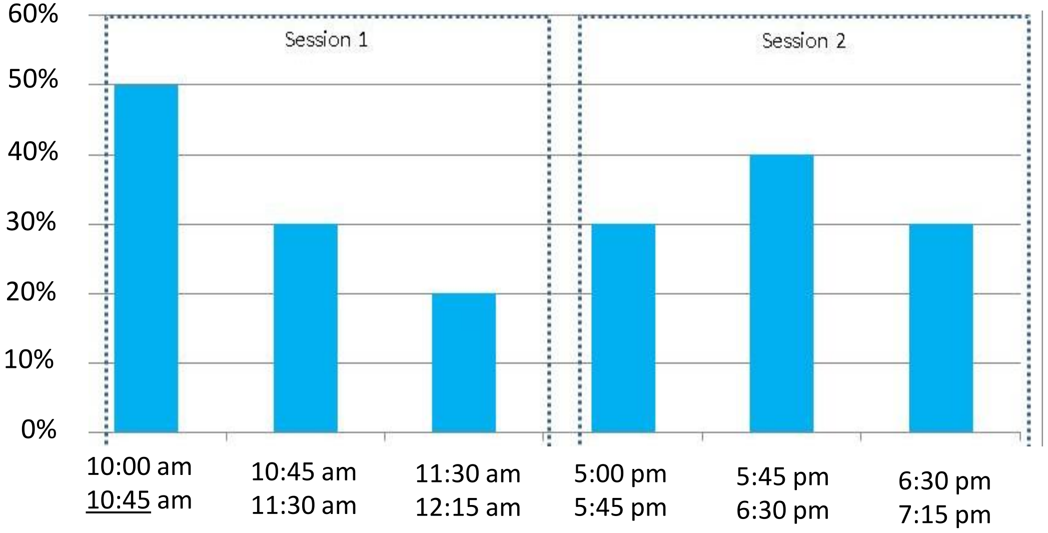
Agents characteristics	Value	Reference
Speed movement	1 m/s	ISO 16738 – Annex G, Table G.4
Shoulder diameter	40 cm	This value was the maximum to guarantee a correct execution of the simulation. (using Pathfinder 2021.3 that was not yet optimized for the ingress modelling). The diameter has been reduced in order to allow agents to navigate properly in narrow geometries of the arena and don’t stick out before getting to their seats.
Social distancing	1 m	Recommendations of the Italian Ministry of Health used in ingress and ordinary egress scenarios.

Pedestrian analysis: crowd data

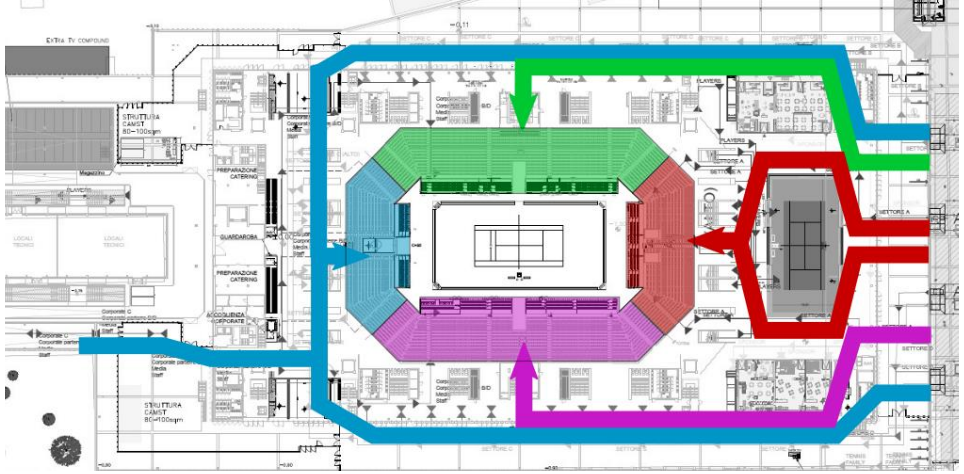
Ingress

Scenarios	Load factor	Time spent at the entrance check	N° of operators/gate
I0	50%	25 sec/spectator	2
I1			4
I2	75%		
I3	100%		

Expected arrivals curve


% of incoming users to the sponsors village

Ingress pathways according to the ticket sector



Social distancing has been considered

The indoor arena is divided in 4 sectors.

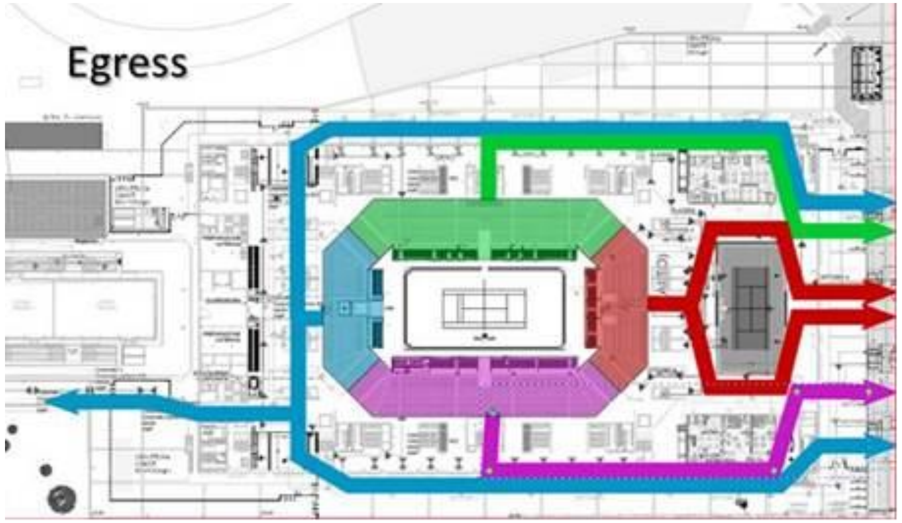
There is a specific correspondence between gates of access and sector of destination

Pedestrian analysis: crowd data

Egress

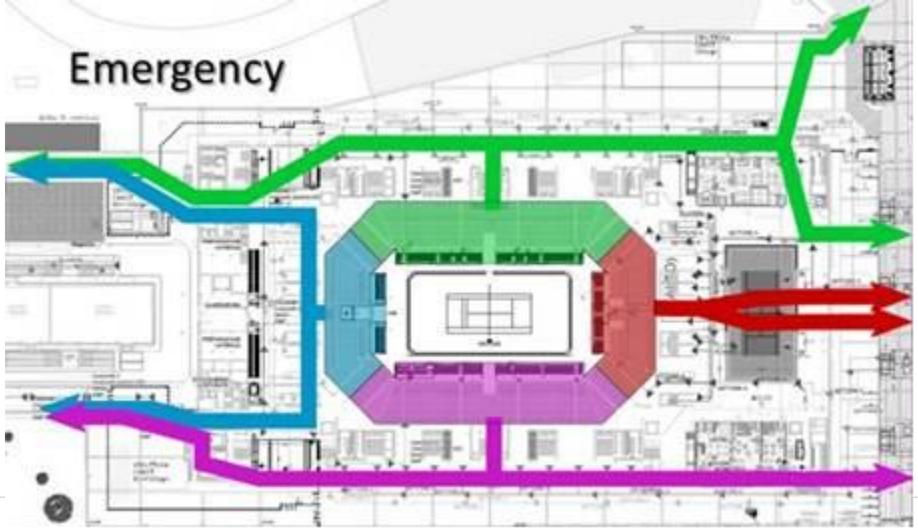
Scenario	Load factor	People in the sponsor village	
A1	75%	45% of the spectators	30% waiting to enter
A2	100%		15% hanging out

Social distancing has been considered



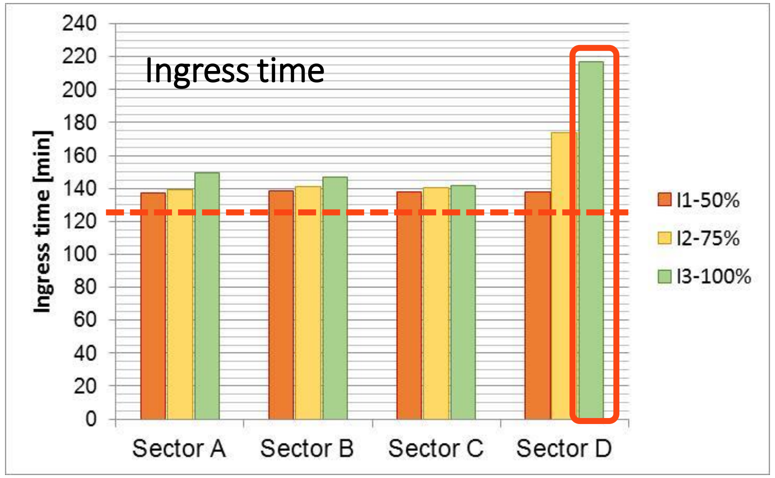
Evacuation

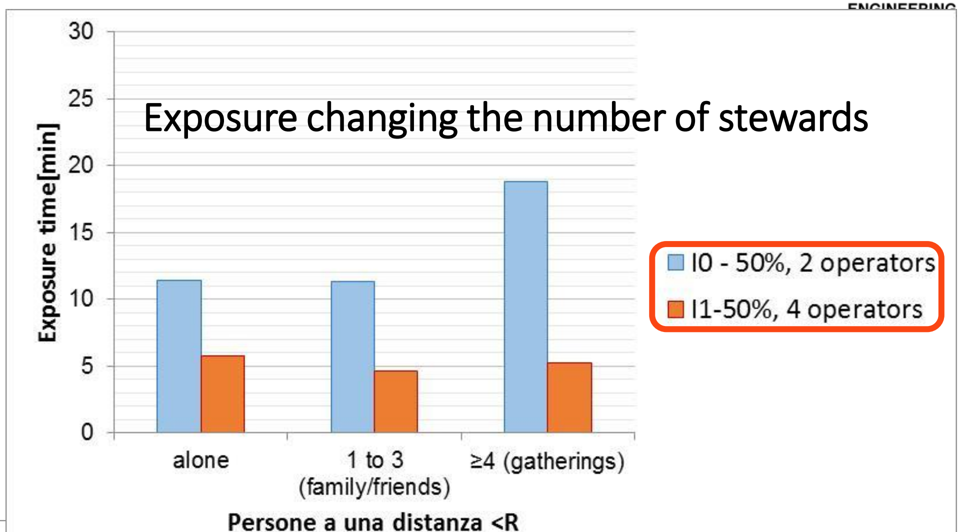
Scenario	Load factor	People in the sponsor village
E1	75%	45% of the spectators
E2	100%	

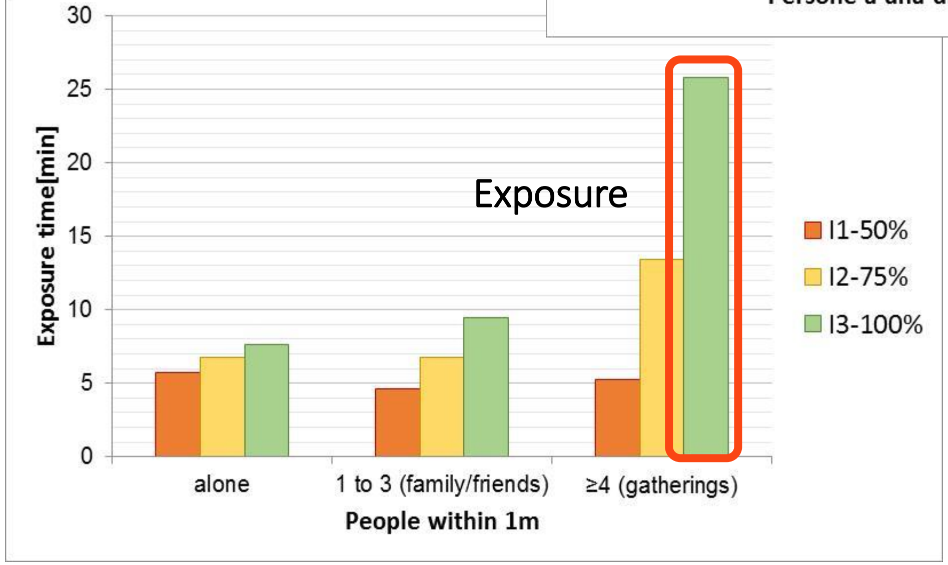


Results (ingress scenarios)

Scenarios	Load factor	Time spent at the entrance check	N° of operators / gate
I0	50%	25 sec/user	2
I1			4
I2	75%		
I3	100%		

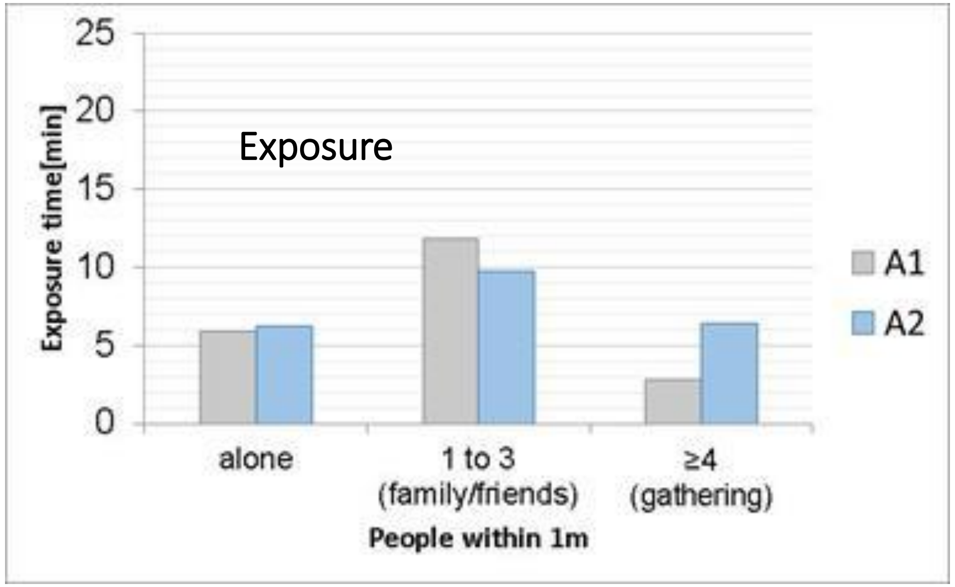




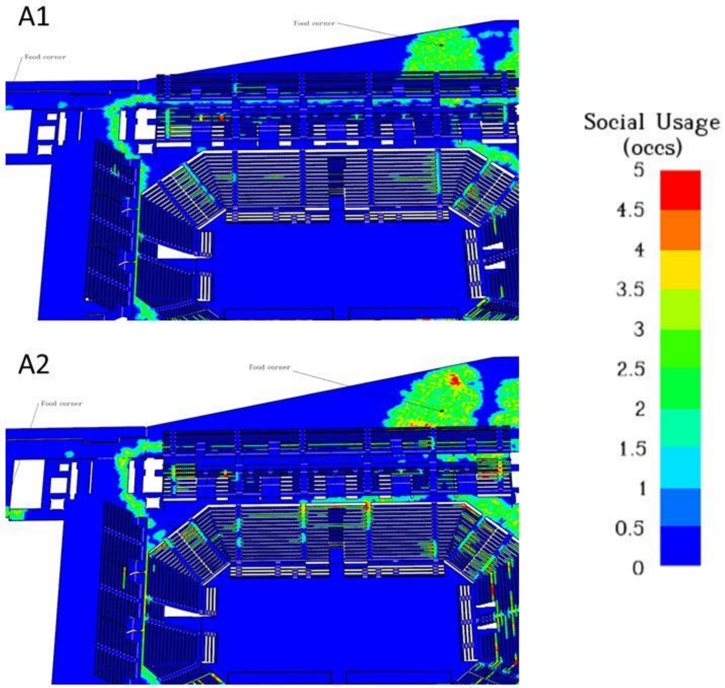


Results (egress in ordinary conditions)

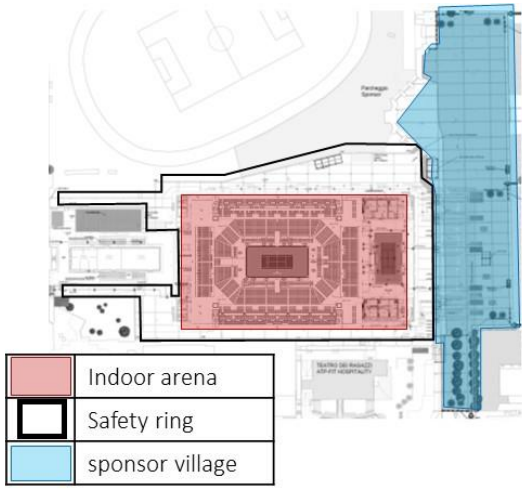
Scenario	Load factor	People in the sponsor village	
A1	75%	45% of the users	30% waiting to enter
A2	100%		15% hanging out



Social usage: during the egress higher values are at the food corner

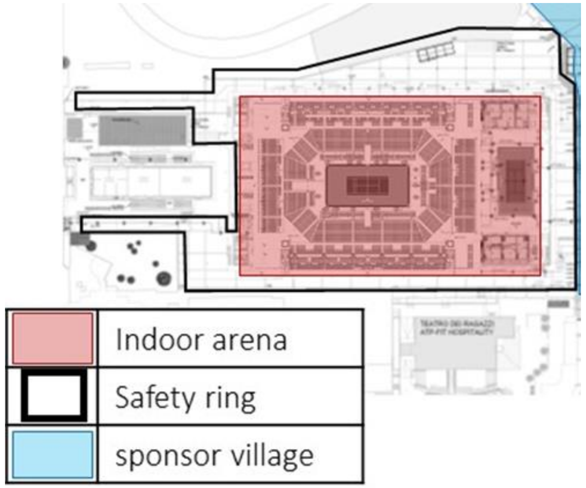


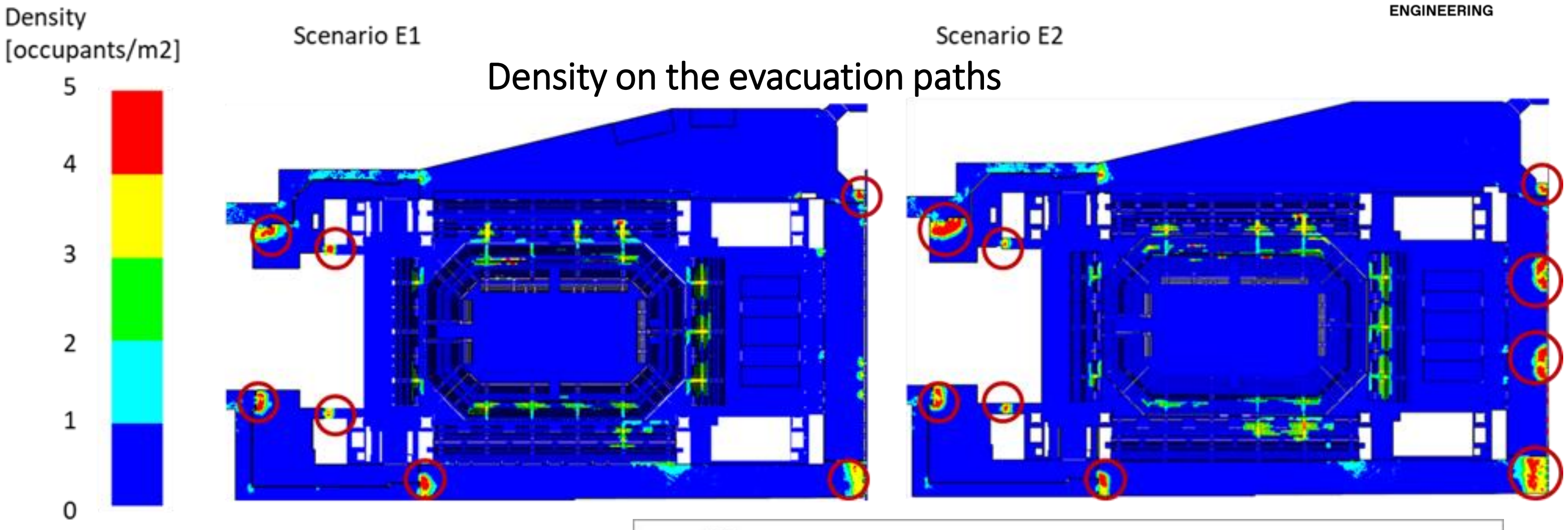
15 minute after the beginning of the egress



Results (egress emergency conditions)

PREDICTIVE
MODELS FOR
ENGINEERING

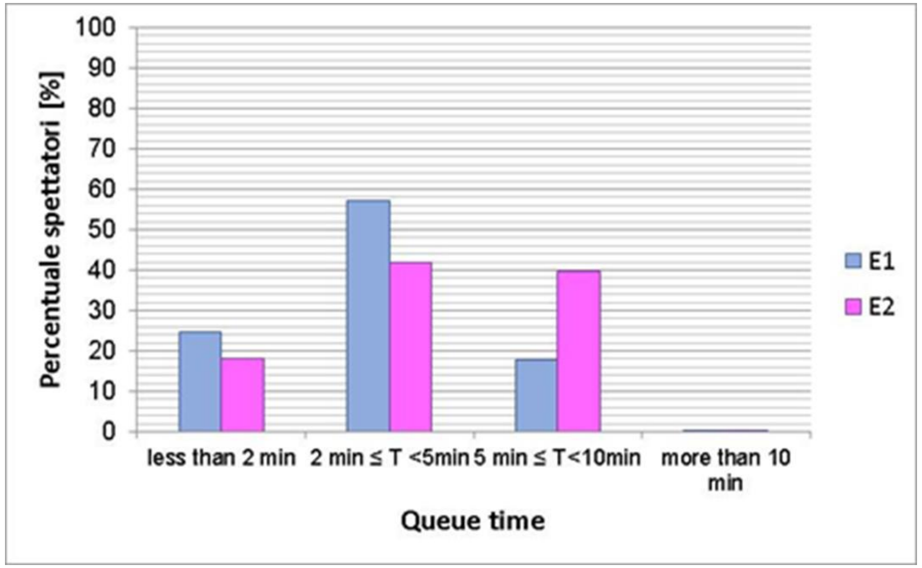




Density on the evacuation paths

Evacuation time from the arena

Scenario	Load factor	t [min]	Green Guide recommendation
E1	75%	7.2	✓
E2	100%	8	



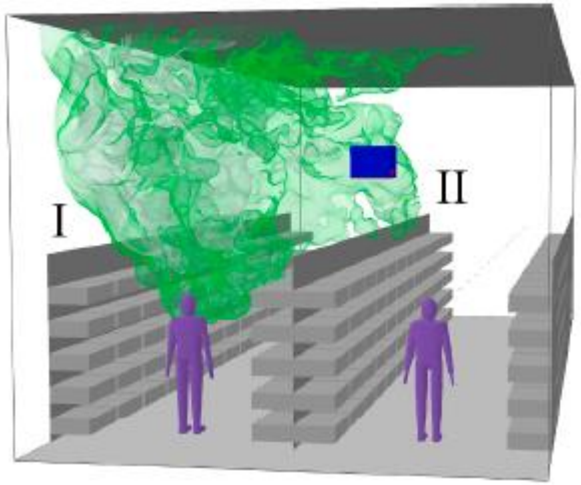
Egress time in emergency is taken in correspondence of the arena perimeter but the queue time is evaluated also in correspondence of the exit at the perimeter of the safety ring.

CFD ANALYSIS

CFD analysis: aerosol characterization

- The aim of analysis was to understand **how the ventilation system affects the distribution of the infected aerosol** emitted by a single person inside the arena.
- Due to the symmetry of the arena and ventilation system, **a quarter of the arena** was modelled and studied by FDS simulations.
- A single person breathing in the arena has been model. The presence of many people creates turbulent mixing of air (due to respiration and movement) not easy to represent in the model. The approach correspond to the one followed by Vourinen and Hostikka in a their recent work.

- **Emission properties**: the emissions and the aerosol properties are taken from literature (*Vuorinen et al, Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors, Safety Science 2020*):
  - ✓ breathing volume flow = 0.014m^3/s;
  - ✓ aerosol mass fraction = 2.7X10^{-4};
  - ✓ aerosol mean diameter = 1X10^{-6}m
  - ✓ Temperature of breathing = 32°C;
  - ✓ T_environment = 20°C;



Vuorinen et al FDS simulation of aerosol dispersion inside a supermarket

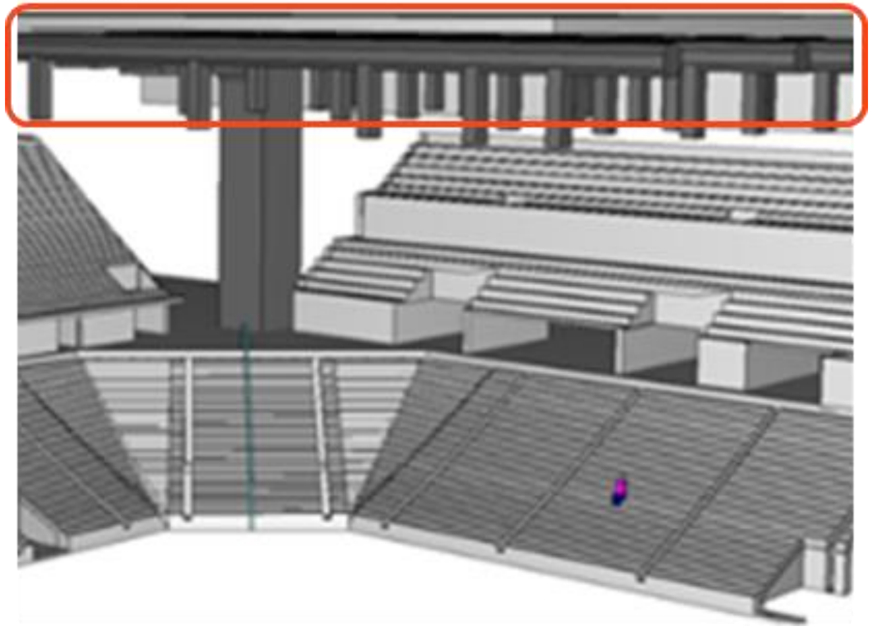
CFD analysis: ventilation system data

Ventilation system: in the model the ventilation system of the arena has been represented as:

- Supply: 168750 m^3/h from the chimneys at the top.
- Extraction: 144000m^3/h extracted from louvers behind the seats;

The system can operate in reverse mode

The fresh Air is pushed from the chimneys



Air is extracted from dampers under the seats

The analysis was finalized to evaluate:

- If an opposite logic of the ventilation provides a better behavior;
- How changes the behavior in function of the airflow rate.

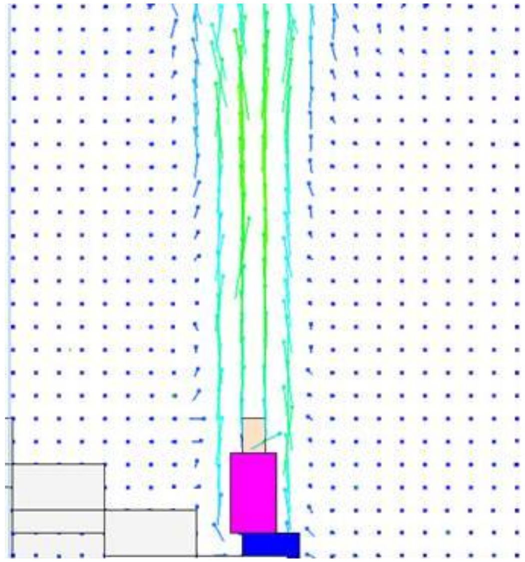
Scenario	HVAC system capacity
1	100%
1_a	75%
1_b	50%
1_c	0%
1_inv	Reverse mode

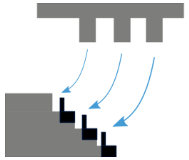
- Scenario 1, 1a, 1b,1c: air is pushed from the top and extracted by the louvers behind the seats;
- Scenario 1_inv: air is extracted from the top and pushed from the louvers behind the seats.

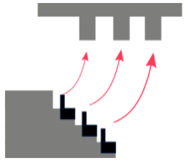
Results (aerosol behavior)

VENT OFF

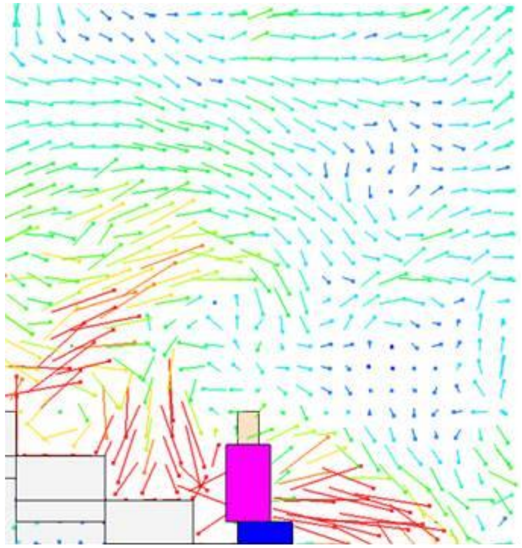
According to Vourinen and Hostikka, the aerosol plume, if there isn’t ventilation forces, proceed on undisturbed

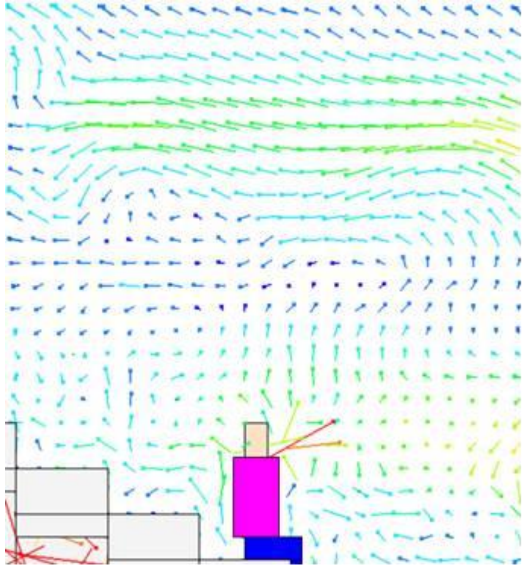






According to Vourinen and Hostikka, the aerosol plume is captured by the ventilation system action and pushed again toward the source (single person)

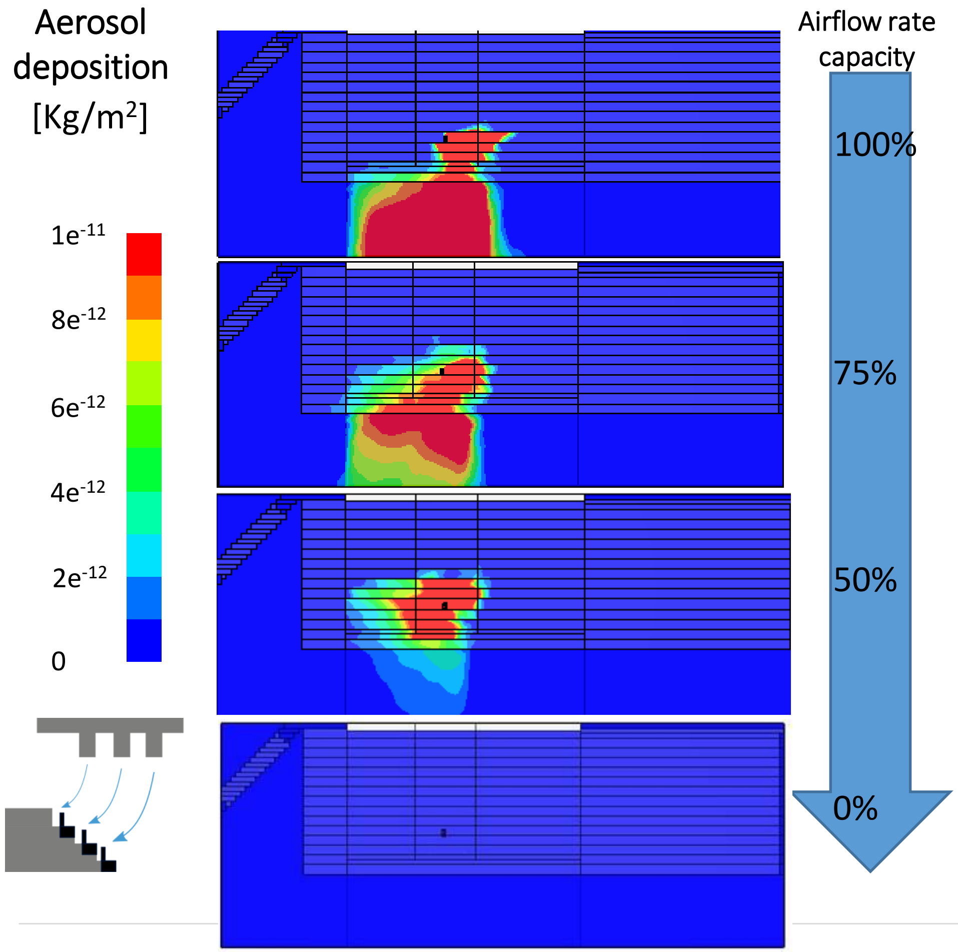




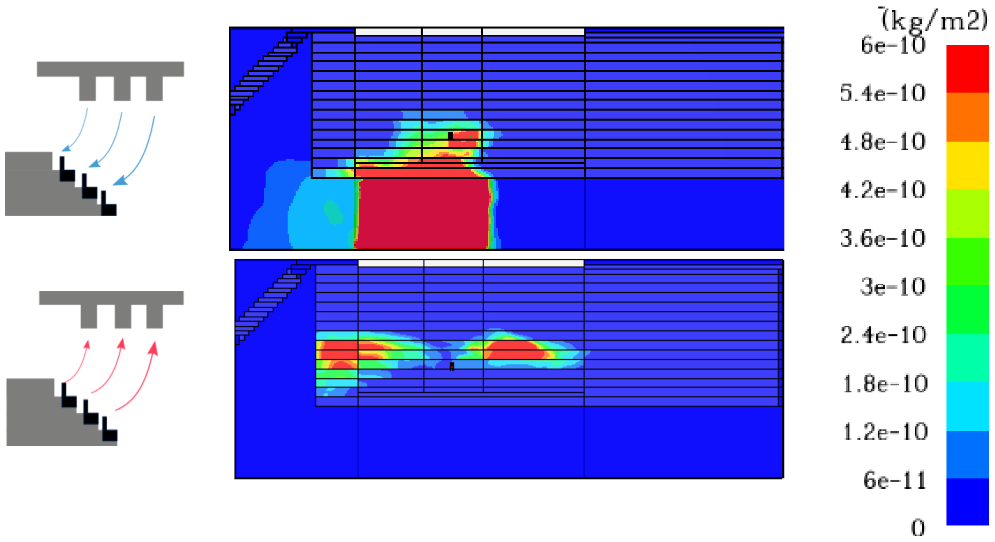
Results (aerosol deposition)

Aerosol deposition for different ventilation regimes

Changing the ventilation system capacity

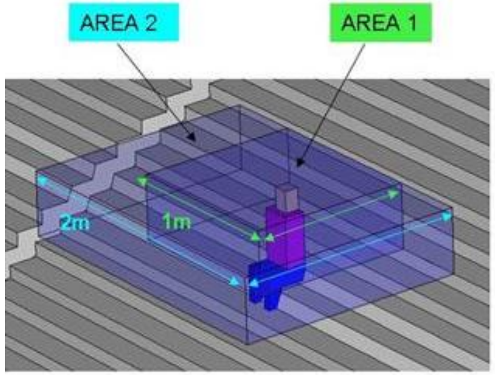


Changing the ventilation system logic

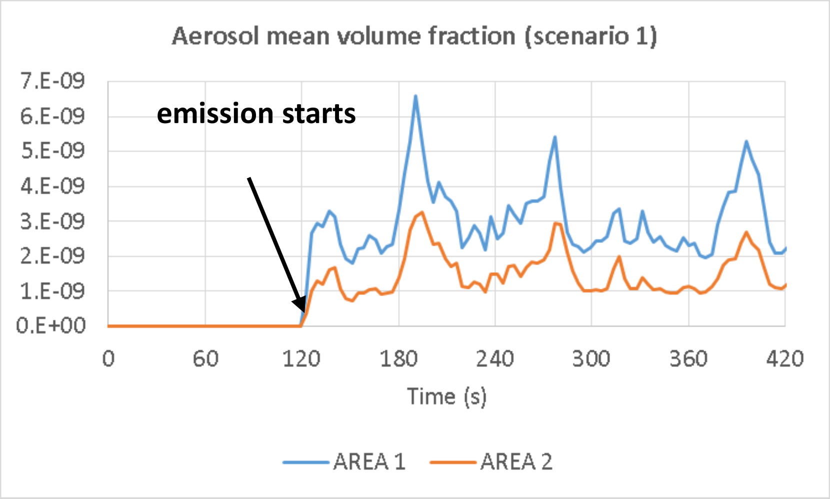


Results (aerosol concentration)

Small control volumes in the vicinity of the emission source

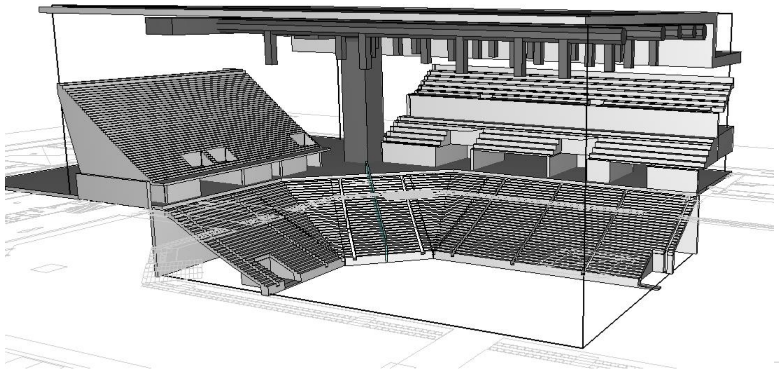


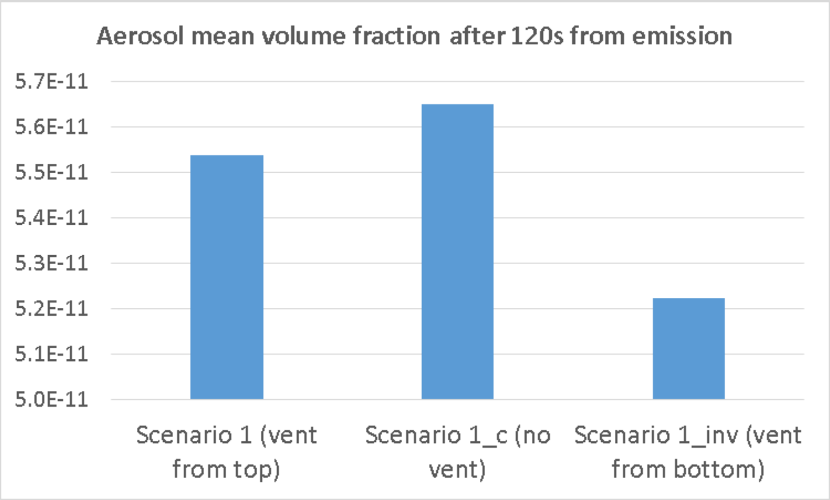
Scenario	HVAC system capacity
1	100%
1_a	75%
1_b	50%
1_c	0%
1_inv	Reverse mode



- Mean aerosol fraction is lower in area 2 than in area 1. This demonstrates that moving away from the emission source, aerosol concentration decreases.
- The irregular trend of mean aerosol fraction is due to the turbulence of air in the vicinity of the emission source.

Control volume including the whole arena quarter

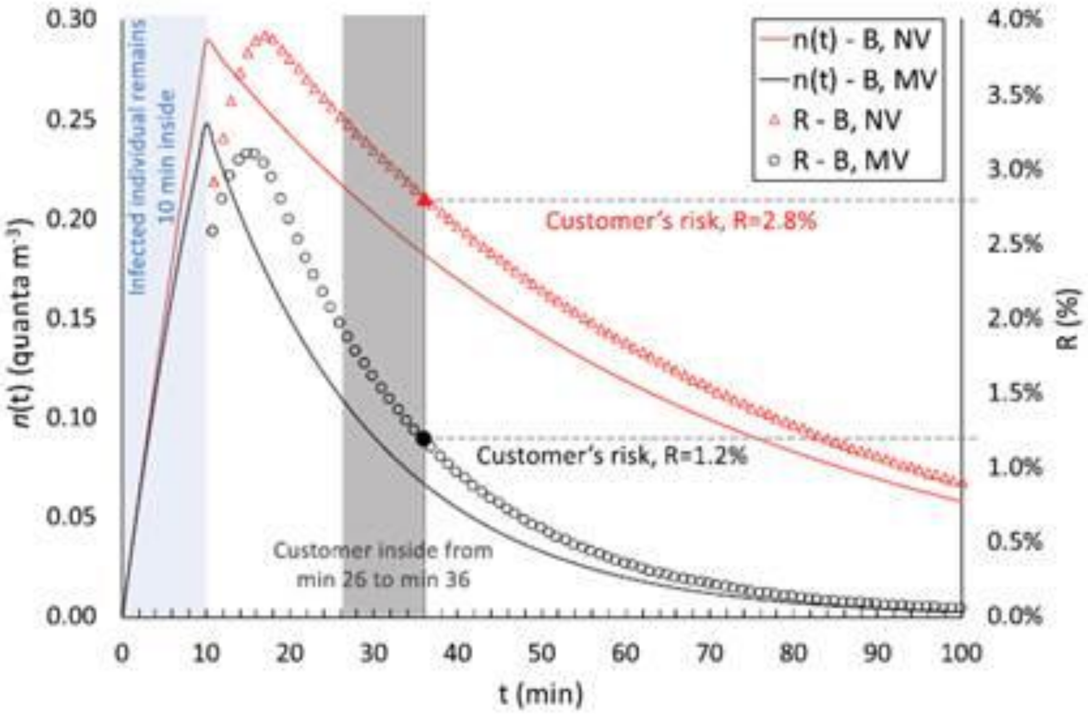



Aerosol mean volume fraction after 120s from emission
5.7E-11
5.6E-11
5.5E-11
5.4E-11
5.3E-11
5.2E-11
5.1E-11
5.0E-11
Scenario 1 (vent from top)
Scenario 1_c (no vent)
Scenario 1_inv (vent from bottom)

Considering the whole volume, the mean aerosol fraction is lower in the mechanical ventilation cases respect to the non ventilated case (accordingly with Buonanno et al.)

Results: comparison with literature

According to Buonanno, the action of the ventilation system has the effect to dilute concentration of aerosols.



In a queue – in a pharmacy queue, indoor environment, according to the test of Buonanno - 10 minutes represent a time interval in which the risk of exposure is "acceptable", less then 1%.

In the region of low mixing, the buoyancy of the exhaled plume effectively removed aerosols from the breathing zone by lifting them upwards.
The mixing ventilation air streams in turn diluted the concentrations in the breathing zone but were also found to capture the buoyant plumes, returning aerosols from the ceiling to the breathing zone.[Vourinen and Hostikka - **Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors**]

cantene

PREDICTIVE
MODELS FOR
ENGINEERING

CONCLUSIONS

Pathfinder improvements

Pathfinder ver. 2021.3

The ingress was modeled using:

- Seats as refuge areas with the maximum capacity equal to 1;
- Reduced dimension of the agents;
- Many profiles to ensure that the arena filled properly.

Pathfinder ver. 2022.2

The ingress can be modeled using:

- Occupants' targets on the rows of the arena. No more refuge areas are necessary;
- The agents can have realistic dimensions;
- Few agents profiles. Only to direct them on the right access gate.

Conclusions

cantene
PREDICTIVE
MODELS FOR
ENGINEERING

- The load factor of 75% was found to be safer regarding the exposure time;
- Ingress phase analysis allows to support the safety plan design putting in evidence the sector D has to be optimized;
- According to the result, to minimize queue time at gates, check activities were split:
  - ✓ the vaccine certification at the safety ring perimeter
  - ✓ The tickets control at the gate;
- The ingress and egress were found to be fast enough to keep short queues for most of the spectators, less than 10 minutes for 80% of the people;
- Operating ventilation system parameters ere defined: airflow rate and direction;
- Egress and emergency egress were found to be safe in its time length and exposure to other spectators.

Thank you for your attention

Cantene S.r.l.
VAT Number: IT09645800013
Address: Via Marco Polo, 24 - 10129 Turin - Italy
Phone: +39 011.19707165
E-mail: info@cantene.it
www.cantene.it