Transmission Risk Modelling for a Multi-Space Office Environment

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PROTECT
A COVID-19 National Core Study

Modelling Aims

The Mechanistic Multi-route Model of Indoor Viral Transmission (M3IVT) [1][2] was created to investigate the transmission of SARS-CoV-2 in an indoor environment. It has been applied to an office with multiple spaces to quantify risks to occupants and to assess the effectiveness of mitigations to inform protection of workers.

Scope of the Scenario

Our modelling focusses on the build up of surface contamination and the dose received by occupants during a single day in a representative office environment. Occupants move around the environment to attend meetings, use the kitchen and toilet and have informal conversations with co-workers. At least one occupant is infectious within each simulation.

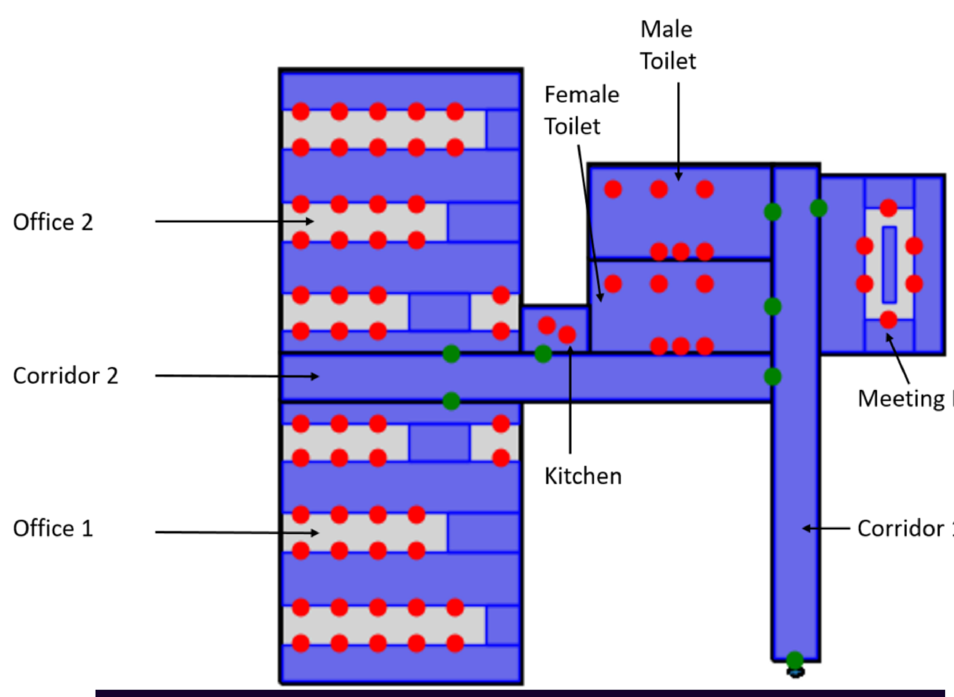


Fig. 1: Office environment layout. Red dots represent fixed positions, green dots represent doors, grey boxes represent desk surfaces.

Mechanics of the Routes of Transmission

Airborne – M3IVT splits the environment into a number of separate well-mixed air zones with averaged concentrations. The infected occupants can introduce airborne virus into a zone through coughing, sneezing and speaking. Airborne infectious concentration in each zone is reduced by fresh air flow, deposition and reduction in viral viability.

Fomite – Virus transfers between hands and surfaces whenever an occupant touches a surface. Transfer is dependent on a large number of parameters [3]. A number of parameter values have been obtained from NCS work packages. Surface touches occur either in a predefined sequence during an occupant activity (e.g. taking the milk from the fridge) or at a specified frequency (e.g. touching of a keyboard). CFD was used to inform the quantity of virus deposited onto surfaces close to the infectious occupant. Occupants can receive a fomite dose by touching their mucosal membranes with contaminated hands.

Close Range – The infectious occupant can deposit droplets directly onto the membranes of occupants in close proximity (<2 metres). The model follows the approach within [4] in that orientation of the infectious occupant is not taken into account.

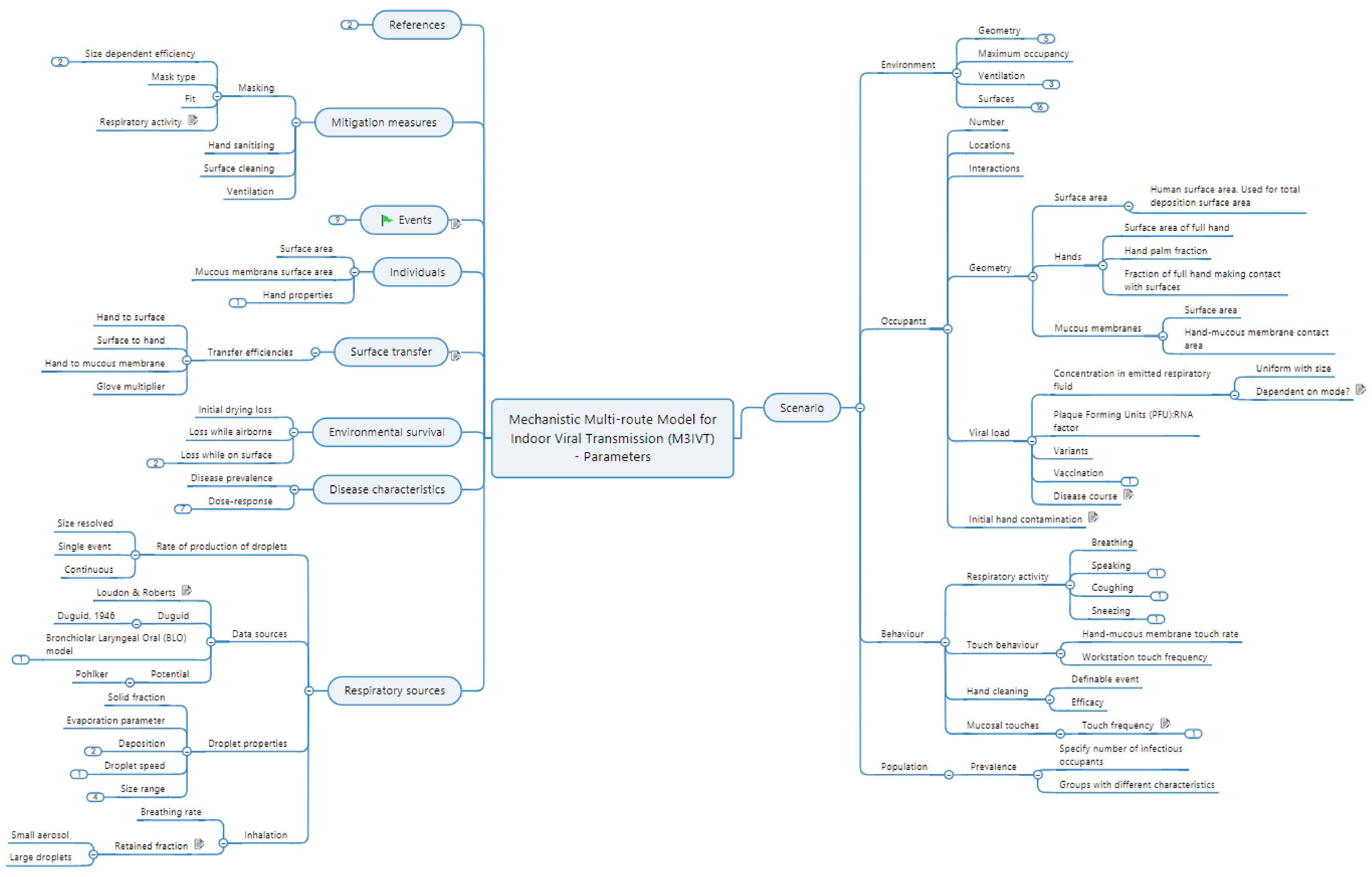


Fig. 2: Input Parameters

Input Data

- The mind map above shows the model inputs (Fig. 2)
- Please speak to one of the team if you have data which could be useful

Zone	Action	Action choices	Probability of choice	Frequency of usage
Kitchen	Make a drink	Hot drink with milk	47.1%	Sampled from truncated normal: $\bar{x}$ = 2 hr, σ = 1 hr, 0.5 hr < x < 10 hr
		Hot drink without milk	18.0%	
		Water	34.9%	
	Have lunch	Add hot water to lunch	5%	Once, between 12:00 and 14:00
		Retrieve lunch from refrigerator	30%	
		Microwave lunch	5%	
		Retrieve lunch from refrigerator and use the microwave	20%	
		Does not have lunch	40%	
Toilet	Use toilet	Use male toilet	50% of occupants are assigned to each toilet at the start of the simulation	Sampled from truncated normal: $\bar{x}$ = 2 hr, σ = 1 hr, 0.5 hr < x < 10 hr (Fig. 3)
		Use female toilet		
		Wash hands	83.3%	
Meeting room	Attend a meeting	2 Occupants	All choices are equally probable (20%). All seat selections are also equally probable (16.7%)	8 times. Meetings commence at 3 minutes past the hour and end 3 minutes before the hour. First meeting at 09:03, final meeting at 16:03.
		3 Occupants		
		4 Occupants		
		5 Occupants		
		6 Occupants		
Office	Virtual meeting	15 minute duration	5%	Between 1 and 3 (sampled from a uniform distribution). Meetings occur on the half hour.
		30 minute duration	10%	
		60 minute duration	70%	
		90 minute duration	10%	
		120 minute duration	5%	
		Speaking proportion	Sampled from truncated normal: $\bar{x}$ = 25%, σ = 10%, 0% < x < 90%	
	Informal meeting	Meeting duration	Meetings can occur with a duration between 1 and 10 minutes (uniformly distributed)	Occupants move to meet other occupants between 1 and 3 times (uniformly distributed) but can have other occupants move to their position any number of times.
Corridor	Time in office environment	Entry time	Sampled from a uniform distribution between 08:00 and 09:00	Occupants may only enter and exit once.
		Exit time	Sampled from a uniform distribution between 7.5hr and 8.5hr after entry	

Table 1: Occupant behaviour decisions and their stochastic probabilities

Planned Simulations

Along with a baseline scenario the impact of the following factors will be investigated:

- Use of face coverings
- Higher/lower ventilation
- Hand sanitising
- Surface cleaning
- Changes to meeting scheduling
- Inclusion of coughing and sneezing
- Changes to transfer efficiencies
- Lower office occupancy
- Lower initial hand contamination for infectious occupants
- Disease prevalence / number of infectious occupants

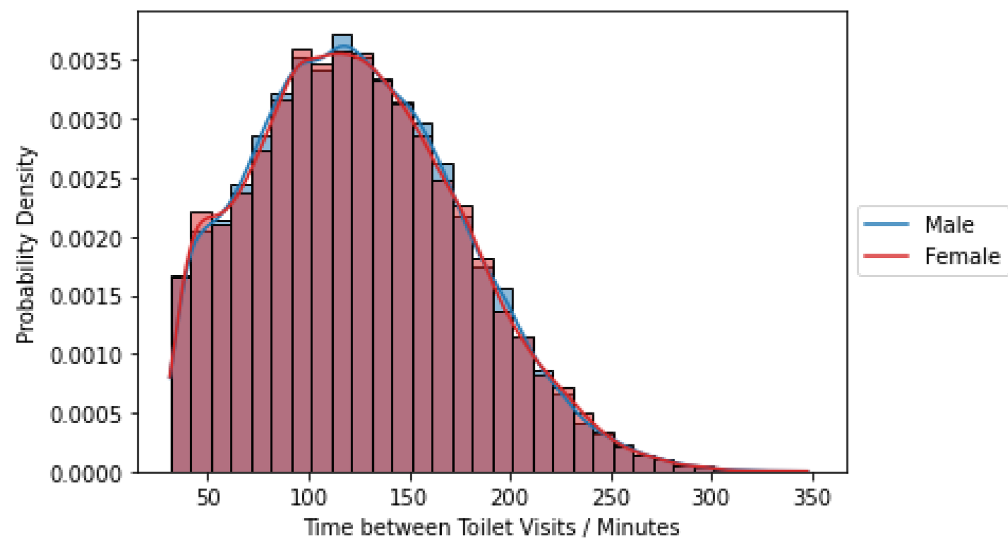
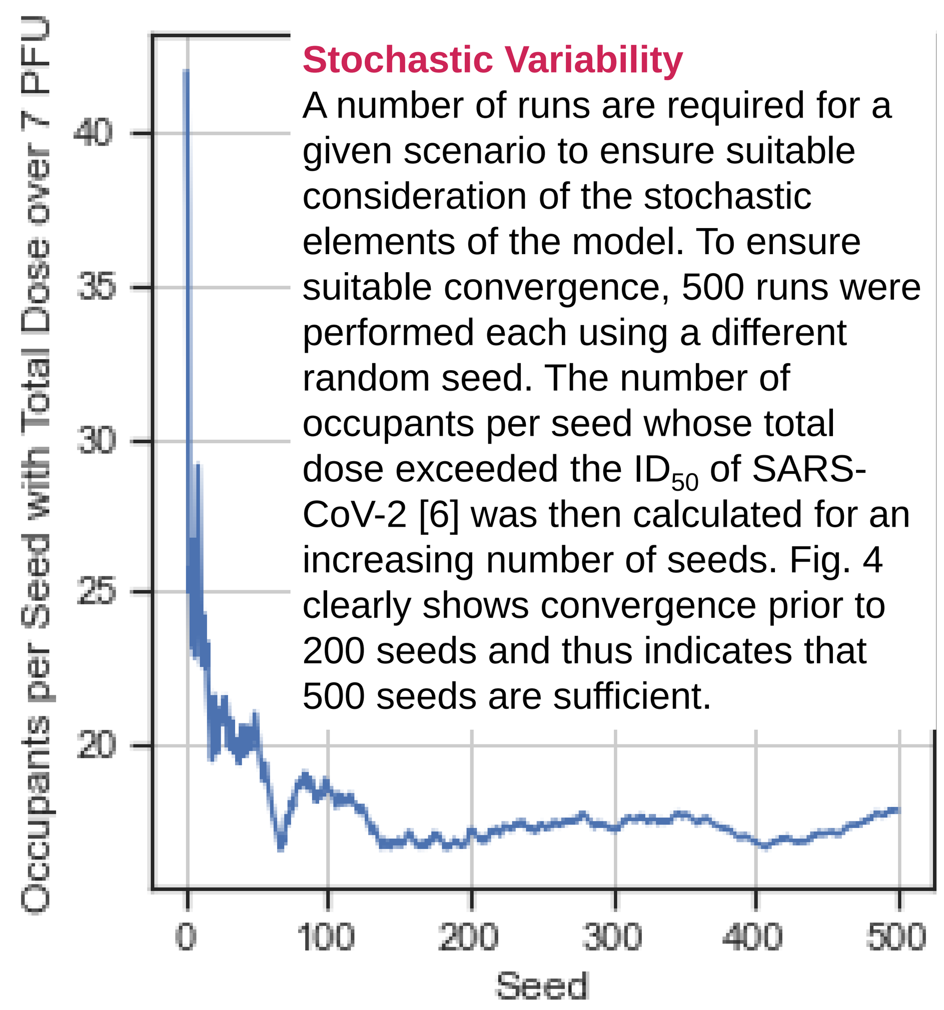


Fig. 3: Distribution of intervals between toilet visits for 500 seeds as an example of stochastic scheduling

Scheduling

- Input files are created using a separate script that generates schedules for each occupant based on a hierarchy of event types defined to give a realistic schedule for the day with no event overlaps.
- Office entry & exit times, meeting room meetings, and lunch breaks are given high priority as these are events that an office worker would primarily schedule their day around. The other event types fit into the gaps in the schedule.
- Most probabilities had to be estimated due to a lack of available data, only drink probabilities had available and applicable data [5].
- Schedules are combined with office geometry in a single input xml file.



Stochastic Variability

A number of runs are required for a given scenario to ensure suitable consideration of the stochastic elements of the model. To ensure suitable convergence, 500 runs were performed each using a different random seed. The number of occupants per seed whose total dose exceeded the ID_{50} of SARS-CoV-2 [6] was then calculated for an increasing number of seeds. Fig. 4 clearly shows convergence prior to 200 seeds and thus indicates that 500 seeds are sufficient.

Fig. 4: Cumulative mean of number of occupants per seed whose total dose exceeds 7 PFU

Output Data

The model outputs the following data for each occupant:

- Final dose split by transmission route.
- Final hand contamination.
- Zones entered and surfaces touched.
- Time spent < 2m from an infectious occupant.

Additionally for every minute in each zone:

- Occupant in fixed position.
- Surface concentrations.
- Airborne concentration.
- Occupant doses.
- Occupant hand contamination.

References

1. Parker, ST, et al., (2022) DSTL/CR138859 V1.0
2. Miller, D, et al., (2022) DSTL/PUB138649 V1.0
3. Miller, D, et al., (2021) DSTL/TR135185 V1.0
4. Lei, H, et al., (2018) Indoor Air 28(3): 398-403
5. UK Biobank [Website], (2022)
6. Killingley, B, et al., (2022) Nat Med

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