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16. Abstract

1 INTRODUCTION
The COVID-19 pandemic exposed how vulnerable air travel is to infectious diseases and prompted stronger federal coordination and integrated research (Sun et al., 2022; GAO 2024). Boeing, the Federal Aviation Administration, Centers for Disease Control and Prevention, and National Research Council Canada formed a multidisciplinary team to tackle communicable disease challenges in aviation and enable rapid public health responses. This collaboration produced the Travel Risk In Pandemics (TRIP-X) framework to assess risk controls and evaluate mitigation strategies for different aviation and travel settings. We present the computational model architecture and methods used in TRIP-X to simulate airborne and fomite transmission in a gate-to-gate air travel scenario.

2 METHODS

TRIP-X is a modular multi-model simulation platform that can simulate infectious disease transmission across varied environments and consists of independent modules.

Geometry & Mesh Generation module auto-generates geometries for aviation environment. Computational mesh resolves the main flow features and near-wall gradients with local refinement regions. Agent-Based Model module describes discrete-event, stochastic agents (passengers, crew, staff) with assigned activities (e.g. boarding, queuing. Behavioral parameters are sampled from empirical distributions derived from NRC & GHD observational studies (e.g., boarding times). Computational Fluid Dynamics module uses steady-state RANS simulations to model the indoor airflow with realizable k–ε turbulence model. Thermal buoyancy effects were included via the Boussinesq approximation.

In Pathogen Dispersion module a modified transport equation is used to model pathogen dispersion for a passive scalar where airborne pathogen concentration satisfies the advection-diffusion-reaction equation with a source term from agent emissions, and a linear term that accounts for removal (deposition + filtration + inactivation). Fomite state variables track deposited viable pathogen load per surface element with decay kinetics and touch transfer events linked to ABM. Epidemiological/Exposure module integrates inhalation doses and fomite contact transfer rates to compute cumulative exposure per agent. Uses dose-response models suitable for novel influenza virus (exponential or beta-Poisson) to estimate infection probability. Produces summary statistics and uncertainty via Monte Carlo repetitions.

Finally, Screening & Scenario Controller module applies pre/post testing, vaccination coverage, mask behaviors, and safety risk management mitigation measures (e.g., modified boarding, enhanced ventilation) to generate alternative scenario inputs.

3 RESULTS and DISCUSSION

Model outputs include time-resolved 3D aerosol concentration plumes that identify spatial and temporal hotspots in a given geometry; surface deposition heatmaps showing accumulated viable pathogen load on high-touch surfaces (armrests, seatbacks, etc.); individual agent exposure time series inhalation and direct contact; and comparative scenario outcomes quantifying the effects of mitigation measures (masking levels, boarding strategies, ventilation changes, surface cleaning, etc.), to be presented in the conference. These outputs collectively demonstrate TRIP-X's ability to resolve both airborne and fomite transmission pathways and to quantify how operational and engineering controls change exposure metrics. It aims to address the lack of a formal national aviation-preparedness plan by providing a structured modeling tool aligned with the International Civil Aviation Organization's SMS framework (ICAO 2018).

4 CONCLUSIONS

By coupling airflow physics, movement behavior, and multi-pathway exposure modeling, TRIP-X reveals how ventilation, occupant dynamics, and surface interactions jointly shape infection risk distributions in transportation environments. The framework provides an uncertainty-aware basis for comparing mitigation strategies and demonstrates the importance of integrated modeling to capture exposure heterogeneity not resolved in single-domain approaches.

5 REFERENCES

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