Estimating Virus Spread With CFD

ASHRAE has published many articles discussing the use of CFD to estimate the spread of viruses from one infected person to another in a space, including "Designing Building Ventilation to Exceed Codes and Standards" by Kishor Khankari, Ph.D., from the June 2025 edition. Although CFD offers benefits in many fields of engineering, including HVAC applications, I don't believe this is one of them. We should not lose sight of the fact that a computer model, no matter how accurate, is still a computer model.

A number of factors cannot be modeled because they are unpredictable. These include, but are not limited to eddy currents caused by people moving through a space and erratic breathing patterns, which can produce powerful intermittent currents. Therefore the variables of volume, velocity and direction are going to be erratic. Sure, you can boil them down to some mean figures, but they would have no correlation with reality.

People may stay in one place for a period of time, but they also move about occasionally and transition in and out of the space. Surely, these transition zones, such as lifts, stairs and corridors would be more likely locations for cross-infection?

None of the articles I have seen deal with asymmetric boundary conditions such as glazing. Although these could be modeled, they would vary with outdoor conditions and introduce another level of complexity.

The Wells-Riley model itself is an over-simplified estimation of enormously complex and infinitely variable flows. Most of the assumptions used in it are questionable. Although the use of CFD is a valiant attempt to address some of them, it leaves uncertainty on the table:

- First, the breathing of all people in the room, as noted above.
- Second, the susceptibility of a person to be infected.

There will also be variability in the size, shape, boundary conditions and occupancy of various spaces. How much effort would it take to analyze each of these, and what could we learn from each one? Would all of this analysis result in a real-world difference?

Although I have no idea how much impact these uncertainties might have, I find it difficult to have faith in modeling attempts for this application. I think this is one of those areas that needs robust debate before we go too far down a path that contains so much uncertainty.

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KHANKARI RESPONDS

Thank you for reading my article and for your comments. CFD is a predictive tool, and no simulation can perfectly replicate physical reality. I agree that the real world encompasses enormous complexity with numerous interrelated parameters. However, this complexity should not discourage us from using predictive tools such as CFD, which can systematically evaluate the physical phenomena affecting the quality of our indoor environments. This is precisely why we should leverage tools such as CFD to advance our understanding of these parameters and their impacts.

Most of the points you raised concern model inputs and boundary conditions for CFD analyses. Fortunately, CFD has advanced sufficiently to address these complexities. Such studies are common in academia, where researchers generate a wealth of knowledge. You can find answers to many of your questions in various research papers, as this work assists practitioners in using CFD for design analysis and optimization.

The key question is whether all CFD models should include every parameter at the same level of complexity. A pragmatic approach to using CFD in practice is to guide HVAC design without overcomplicating the models. Including all parameters in CFD analyses might render the models excessively complex, making it difficult to draw sensible conclusions in a reasonable time frame and with limited resources. Let's remember that CFD is a predictive tool meant to help us navigate the complexities of our world.

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The Role of CFD in Ventilation Design

June 2025's *ASHRAE Journal* article, "Designing Building Ventilation to Exceed Codes and Standards," by Kishor Khankari, Ph.D., has demonstrated the usefulness of CFD models in evaluating building ventilation performance and IAQ. A CFD model is a tool that can lend itself to designing effective ventilation systems in terms of indoor airflow patterns and pollutant spread. A design process, however, also involves other crucial considerations including electrical/mechanical and fire protection codes, controls and constraints such as cost. Given the article's limited scope, using the phrase "designing building ventilation" in the title can be misleading. Similarly, for clarity, it should specifically refer to ASHRAE codes and standards.

Computational mesh and turbulence model have been cited as factors influencing the accuracy of the CFD predictions without elaborating. In addition, other inherent errors stemming from discretization of the differential equations, boundary conditions and assumptions should be explicitly stated.

Collectively, these sources of inaccuracies can lead to significant uncertainties in the results, including performance metrics (e.g., spread index and purge time). Although the study alludes to the necessity of sensitivity analysis for accuracy assessments, it lacks evaluation of the uncertainties for the results—which is a prerequisite to validation of the simulation model. Ultimately, the actual IAQ in the breathing zone is also subject to flow disturbance and spread of contaminants arising from stochastic elements such as occupants' behavior and movements.

Furthermore, seemingly absent from the study is an examination and/or acknowledgement of the effects of daily and seasonal variations in the HVAC mode of operation on the overall building ventilation performance. Therefore, without such assessments, uncertainty estimates, and model verification thereof, the article's assertion that CFD models can help optimize the ventilation performance and exceed the codes and standards may be deemed unsubstantiated.

Although the advantages of computational models over experimental work are indisputable, it would be worthwhile to reflect the importance of analytical, experimental and field-test assessments. In fact, these techniques can support model development and play an important role in the validation process. Providing a description of CFD modeling challenges, especially for the presented case studies, is recommendable. Not only will such an addition be enlightening, but it will also help improve the quality and objectivity of the article.

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KHANKARI RESPONDS

Thank you for taking the time to read my article and for your insightful comments. The primary intent of the article is to emphasize that while codes and standards are essential, they are not sufficient to ensure adequate IAQ. ASHRAE standards are mentioned merely as an example of the prescriptive nature of such codes and standards. Although I agree with your points regarding other aspects of building design, the focus of the article is specifically on ventilation design.

I appreciate your comments about the fidelity of CFD models. You are correct that various parameters related to both the computational process and the input provided to CFD analyses can affect the outcome. The appropriate fidelity level for a CFD model depends on the objectives of the analysis, considering the balance between modeling efforts and the associated benefits. Additionally, we must take into account the required expertise, costs and available resources for conducting high-fidelity CFD analyses.

It's important to remember that CFD is a predictive tool designed to assess the relative merits of different design alternatives and guide ventilation design to meet the specific needs of a space. Indeed, CFD can also be employed with high-fidelity models to validate CFD results against experimental and field tests.

We should strive to elevate our design efforts beyond basic practices and incorporate predictive tools like CFD to address the needs of the modern world, ultimately advancing the arts and sciences of HVAC for the benefit of humanity.

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