When will your elevator arrive? Two physicists do the math

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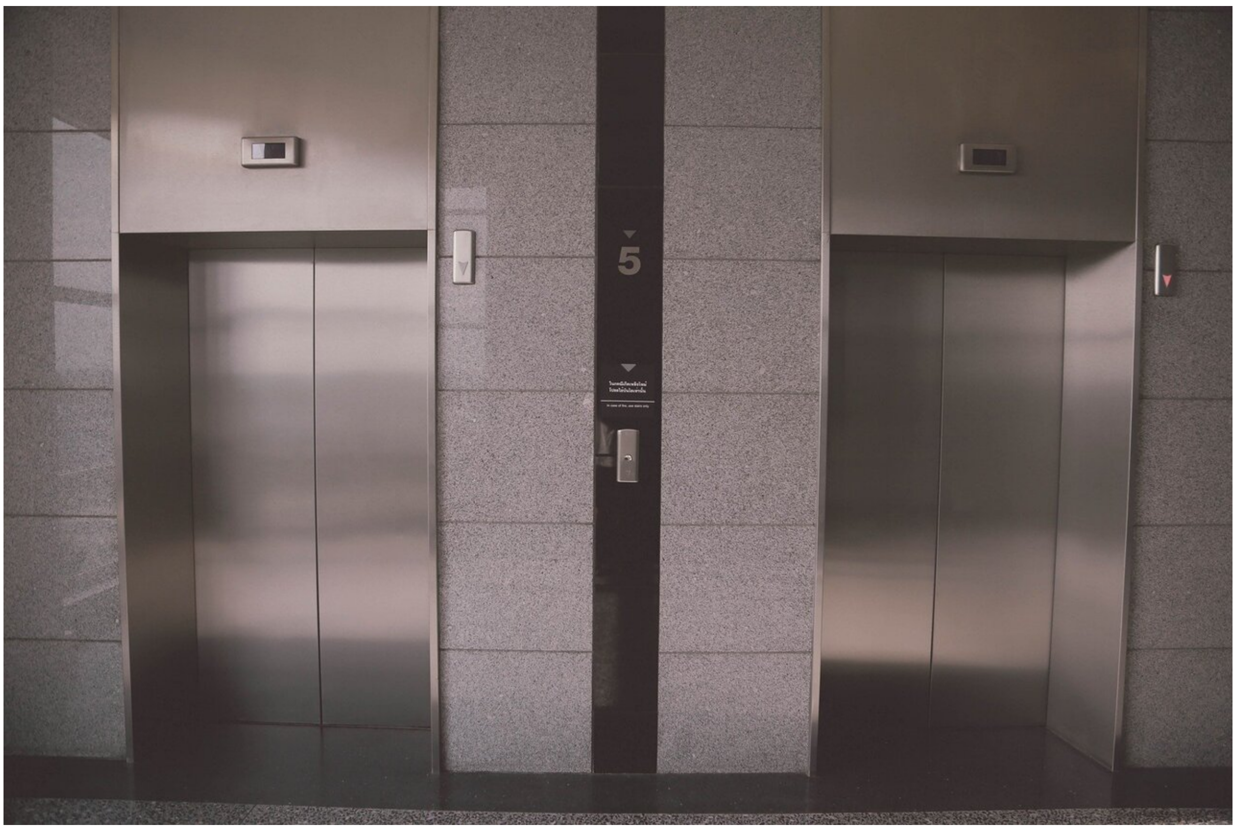

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The human world is, increasingly, an urban one—and that means elevators. Hong Kong, the hometown of physicist Zhijie Feng (Boston University), adds new elevators at the rate of roughly 1500 every year...making vertical transport an alluring topic for quantitative research.

"Just in the main building of my undergraduate university, Hong Kong University of Science and Technology," Feng reflects, "there are 37 elevators, all numbered so we can use them to indicate the location of hundreds of classrooms. There is always a line outside each elevator lobby, and if they are shut down, we have to hike for 30 minutes."

Feng and Santa Fe Institute Professor Sidney Redner saw this as an opportunity to explore the factors that determine elevator transport capabilities. In their new paper in the *Journal of Statistical Mechanics*, they begin by making a deliberately simple "toy" model.

"Engineers have already developed computational models for simulating elevators as realistically as possible," says Feng. "Instead, we wanted insight into basic mechanisms, using just enough parameters to describe what we see in a way we can fully understand."

Their minimum-variable simulation makes six key assumptions: unoccupied buildings, first-come-first-served transport, identical elevators traveling to uniformly distributed destination floors, 2.5 seconds to enter or exit elevators, and one second to travel from one floor to the next.

For a 100-story building with one idealized infinite-capacity elevator, Feng and Redner find that waiting times typically fall between five and seven minutes. With elevators that can carry 20 people each, and buildings that hold 100 workers per floor, this cycle requires 500 trips over 2 hours—or 21 elevators—to get everyone to work on time.

"If the elevators are uncorrelated," the authors write, wait time "should equal the single elevator cycle time divided by the number of elevators, which is roughly 15 seconds." However, this efficient spacing of elevators doesn't last: as passenger demand increases, elevators start to move in lockstep, creating traffic jams in the lobby below until multiple elevators arrive back on the ground floor at the same time.

These nonlinear dynamics stymie any easy answer to the question of how long a person has to wait. But to Feng and Redner this is just the entry-level to a bigger inquiry. "I hope our work could be a 'pocket version' model to extend from," Feng remarks. She credits Redner's textbook, which she read in her early undergraduate days, for inspiring her love of breaking down complex problems into simple models.

Some of the further questions they identify include, "If a building tapers with height, is there a taper angle that minimizes waiting time but optimizes office space?"; and, "What if some elevators only service certain floors, and others service different floors?"

Food for thought next time you're waiting in the lobby...

More information: Zhijie Feng et al, When will an elevator arrive?, *Journal of Statistical Mechanics: Theory and Experiment* (2021). DOI: 10.1088/1742-5468/abf7b6

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