Designing Safe Elevator Systems amidst a Pandemic

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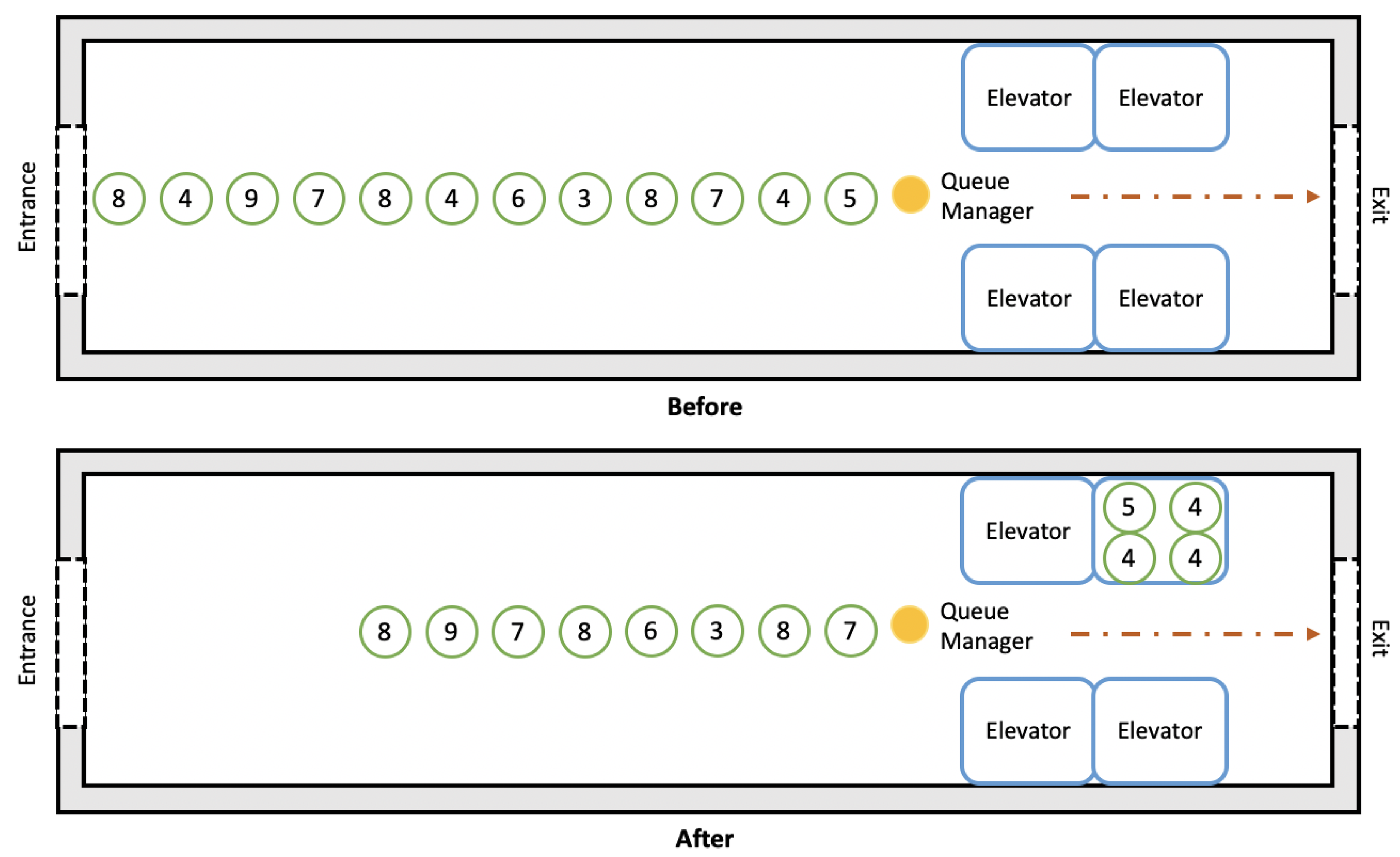
Introduction

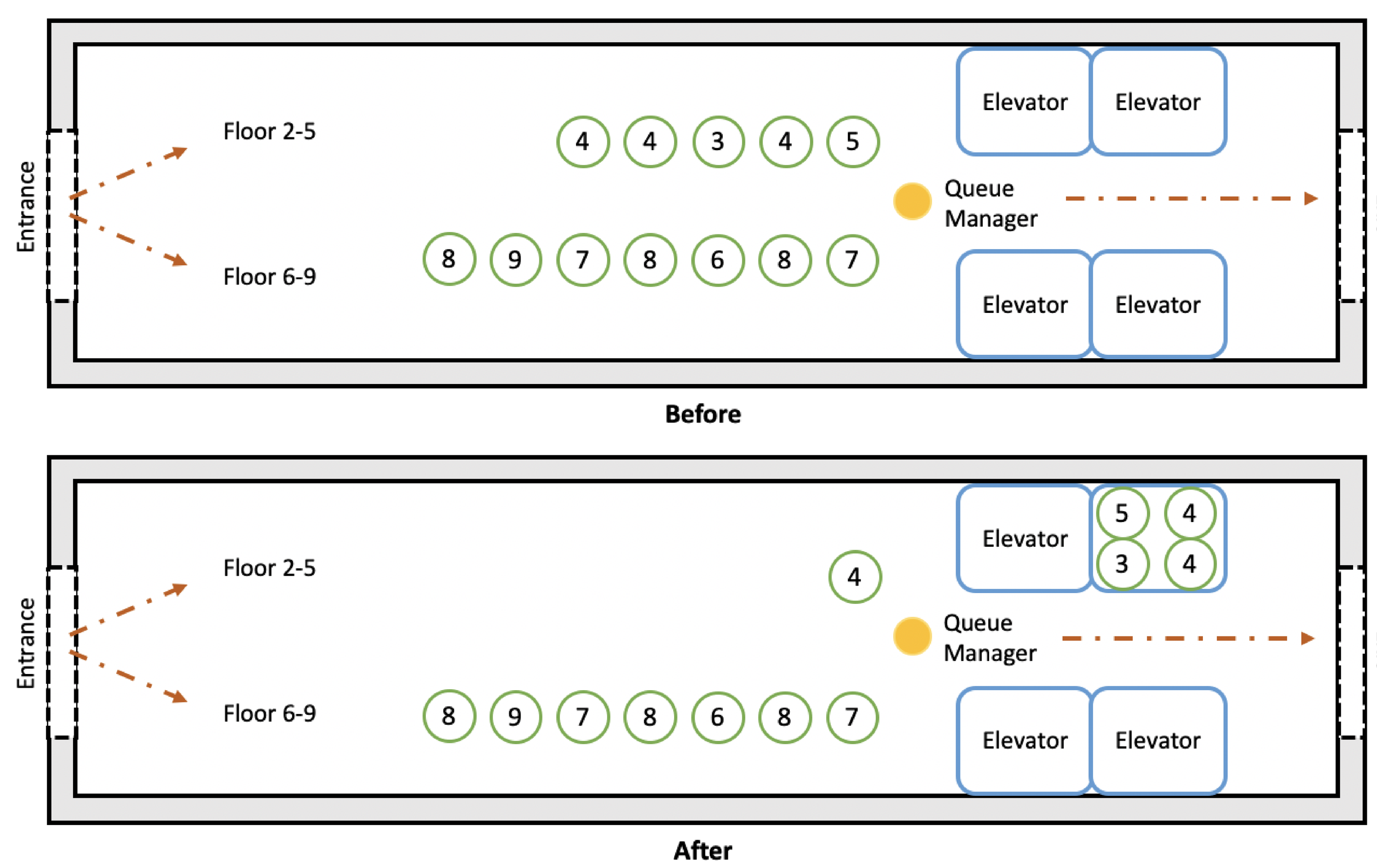
- The requirement of social distancing during the COVID-19 pandemic has presented significant challenges for high-rise buildings, as the elevator capacity has been reduced by over half the normal amount. This reduction is a serious concern, as reduced elevator capacities cause large queues to build up in lobbies, which makes social distancing a challenge.
- We use mathematical modeling and epidemiological principles to design interventions for safely managing elevator systems amidst a pandemic.
- **Objective:** Propose simple interventions for safely managing the elevator queues that drastically reduce the waiting time and length of lobby queues.

Possible Interventions

- **Cohorting** — A queue manager (QM) seeks to group together passengers going to the same floor, allows some passengers to jump the line.
- **Queue Splitting** — QM asks passengers to join the queue corresponding to their floor group and elevators are boarded from the queues in a round robin fashion.



An illustration of the Cohorting intervention



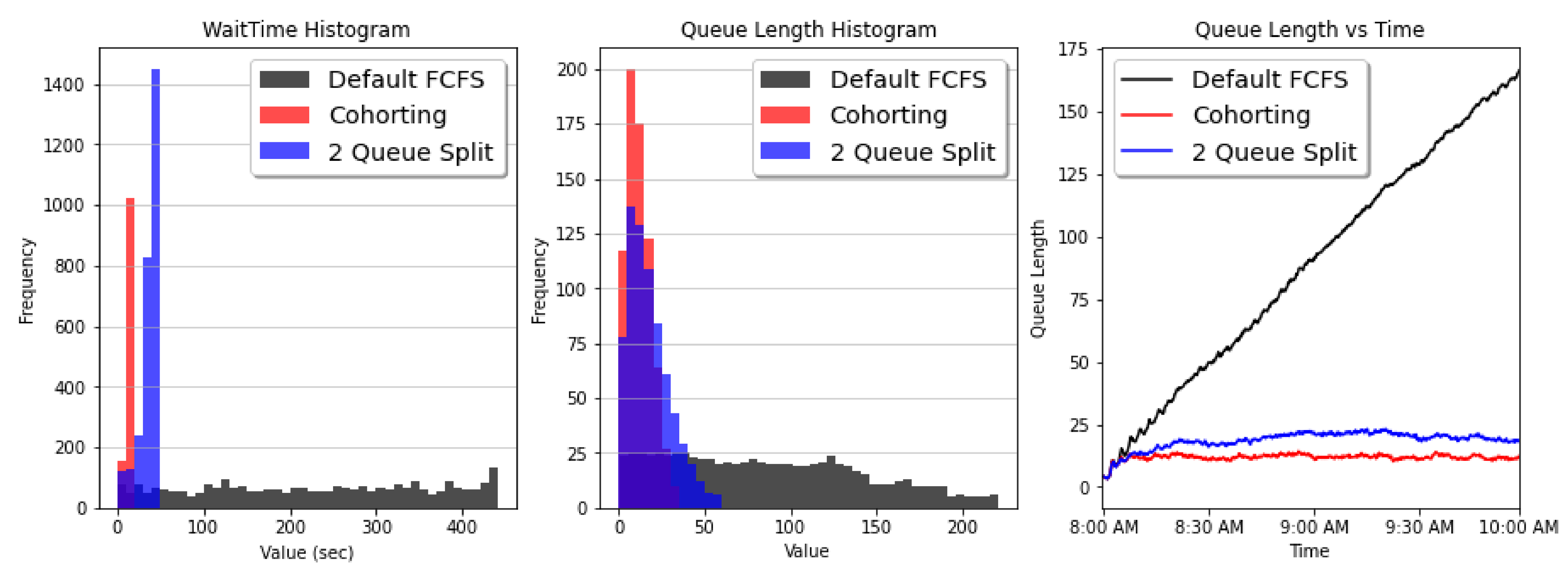
An illustration of the Queue Splitting intervention

Simulation Design

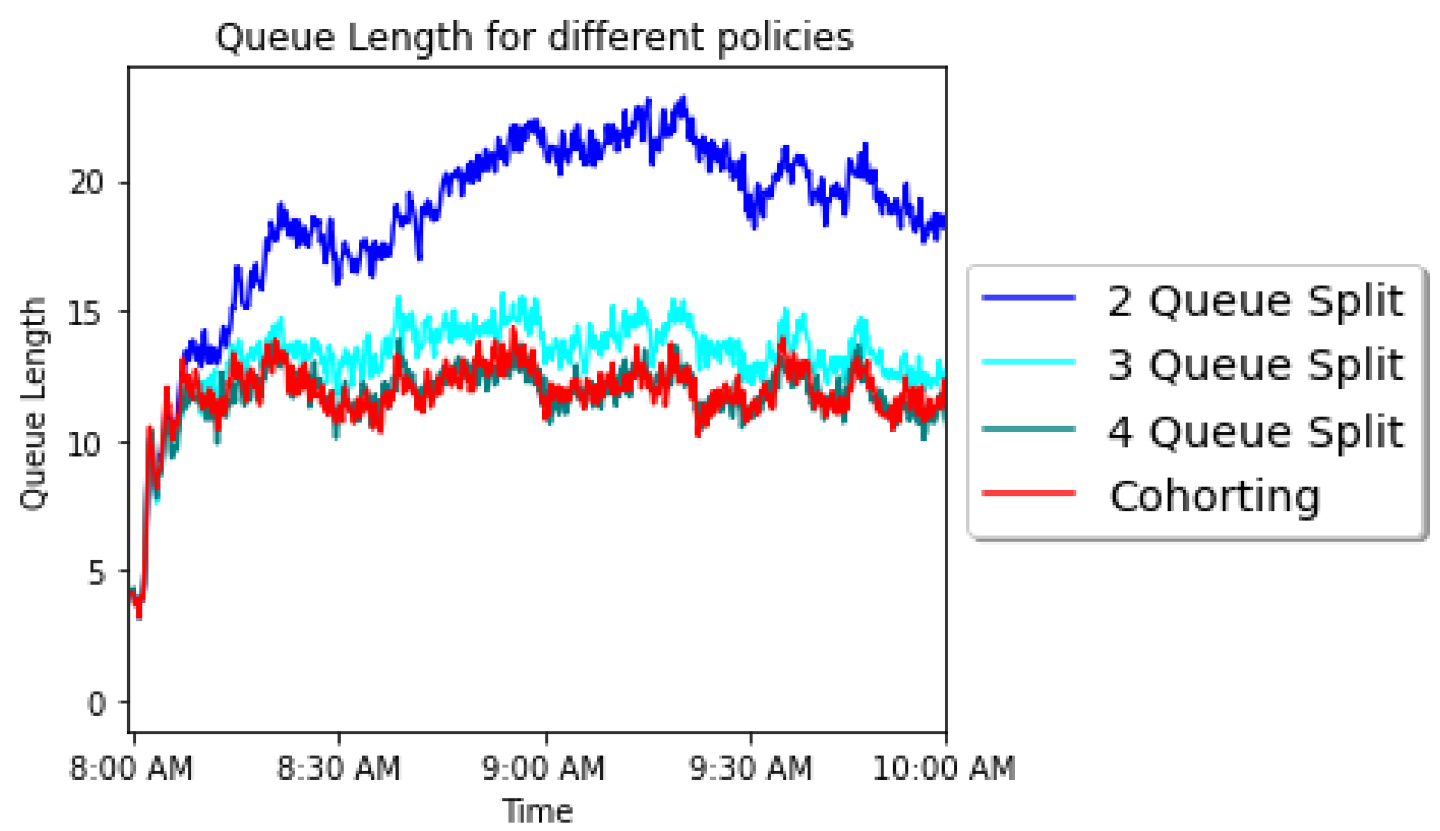
- Our simulation model uses data from a large government building in New York City that is planning for re-opening. In particular, it is a historical building with a legacy elevator system, so that only technology-free solutions can be implemented.
- The building has 25 floors and the 14 elevators (each with capacity 4) serve about 2750 visitors during the morning rush hour (8-10 AM).
- Passengers arrive at the (1st floor) lobby according to a Poisson process.
- The interventions are compared to a benchmark known as First-Come-First-Served (FCFS), where the passengers who arrive at the lobby first will enter the elevator first. This is the default with no intervention.

Results

- We evaluate the performance of each intervention on 100 independent random scenarios and report the average performance.

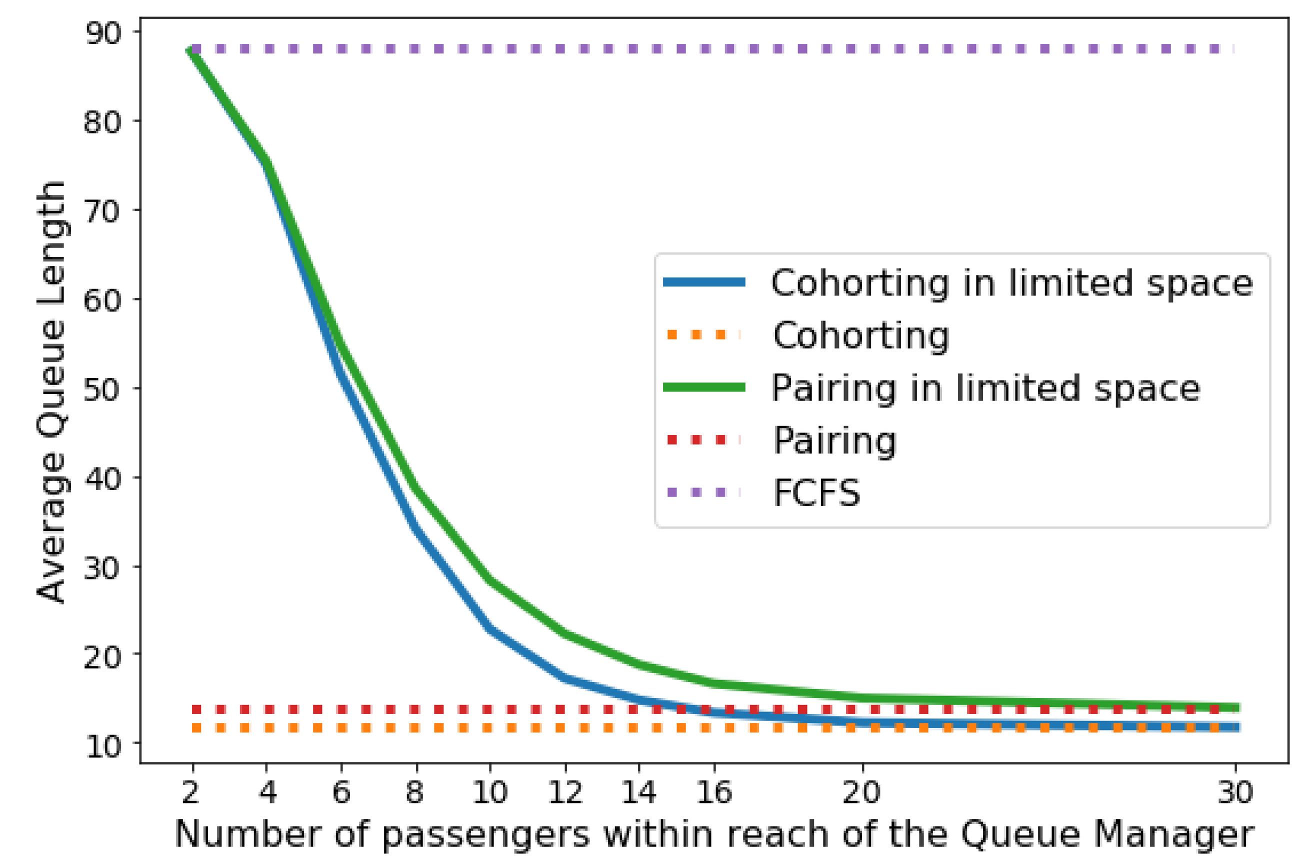


- Under the default FCFS policy, the wait times grow almost linearly, as does the number of people in the lobby. In fact, by the end of the rush hour, there can be up to 160 people in the queue. It is clear that an intervention is absolutely necessary to avoid this unsafe buildup of passengers.
- Both Cohorting and Queue Splitting can drastically reduce the waiting time and queue length, since the number of stops per elevator trip is implicitly reduced significantly.



Practical Issues

- In practice, the Queue Splitting intervention requires enough space in the lobby to safely keep the distance between different queues.
- Cohorting requires the QM to ask if anyone in the queue going to the same foor as the first passenger. This theoretically means the QM can talk to anyone in the line, no matter how long the queue is.
- We propose Cohorting in limited lobby space that the QM can only reach out to a certain number of passengers in the queue.
- Another issue is the extra time Cohorting may take, which could delay the elevator boarding process if the communication takes an excessively long time.
- We propose the Cohorting with Pairing intervention, which only requires the QM to find one passenger with the same destination as the first person and create a "pair" to board the same elevator.
- We observe a good performance when cohorting (pairing) in limited space when the QM can talk to more than 10 passengers.



- Cohorting with Pairing is an effective and easy-to-implement intervention, as it performs almost as good as the Cohorting intervention.

Conclusions

- Cohorting and Queue Splitting can significantly improve efficiency and drastically reduce the queue length.
- The Queue Manager can simply implement the Cohorting with Pairing intervention in a limited lobby space.
- The interventions we propose do not require programming the elevators.
- The interventions apply to generic high rise buildings. We also report similar results for low and medium sized buildings.

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