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OPTIMAL SCHEDULING OF A MULTI-CLINIC HEALTHCARE FACILITY IN THE COURSE OF A PANDEMIC

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ABSTRACT

Due to the social distancing requirement during the COVID-19, the elevator capacity in high-rise buildings has been reduced by 50-70 %. The reduced elevator capacity results in queue build-up and increases the elevator wait time, which makes social distancing challenging in the lobby and elevator halls. This could increase the chance of the spread of the disease and would pose significant safety risks. Therefore, it is necessary to design an intervention that could help safely managing the elevator queues and reduce the elevator wait times. In this work, we focus on minimizing the elevator wait time in a multi-clinic facility by controlling the people arriving at the elevator halls, which is possible by optimizing the clinic schedule.

1 INTRODUCTION

Due to the social distancing requirement during the COVID-19, the elevator capacity in high-rise buildings has been reduced by 50-70 %. The reduced elevator capacity results in queue build-up and increases the elevator wait time, which makes the social distancing challenging in the lobby and elevator halls. This could increase the chance of spread of the disease and would pose significant safety risks. Therefore, it is necessary to design an intervention that could help safely managing the elevator queues and reduce the elevator wait times. In this work we focus on minimizing the elevator wait time in a multi-clinic facility by controlling the people arrival at the elevator halls, which is possible via optimizing the clinic scheduling.

2 MODEL AND METHODOLOGY

Consider a clinic building with a set of floors $F = \{0, 1, \ldots, N_F\}$, where floor 0 is the lobby. At each floor $f > 0, N_c^f$ clinics are located, where clinics can be thought of as tied to individual doctors. For example, "nephrology" may have 3 doctors seeing patients on a given day, so we will consider those as 3 clinics. We assume a central building planner that has some ability to schedule the clinic start times. While this may not be reasonable in an office tower, it may be reasonable in an entire facility dedicated to patient care, run by the government. Our objective is to minimize average wait time for an elevator, and our decisions is to set the start times of clinics. The number of patients to be visited by clinic C_l is n_l, which we assume is exogenous. We assume patients at each clinic are scheduled back to back at intervals equal to the appointment duration, τ. We assume a no-show probability of zero, so patients will arrive at scheduled times.

The operating time of the building is H time units. Building has N_E elevators, indexed as $E = \{1, \dots, N_E\}$, each with capacity C. An elevator $E_e = (f_e^c, f_e^d, F_e)$, is situated at current floor f_e^c, moving toward destination floor f_e^d, and is planned to stop at floors F_e. The system state is

$$\omega = (\{R^f : f \in F\}, \{f_e^c, f_e^d, F_e\} : e \in E),$$

which consists of set of all waiting requests, R^f, as well all elevators' information. There are different ways of deciding which elevator should handle a request, but we assume a simplified pickup rules for the elevators as follows, which is inspired from literature: every elevator car maintains its upward (downward) direction of motion if there are up (down) hall calls at floors above (below) the current floor of the elevator car, and if not, the car moves to the highest (lowest) floor at which downward (upward) hall call exists.

In addition to the theoretical model, we have developed a discrete event simulation model of the problem, into which we have loaded the elevator control algorithm. The elevator algorithm in our simulation model is developed based on the existing models in the literature (see Dagdelen et al. 2005, for example), and has been modified to have the flexibility to be adapted to any building. As a result, our simulation model can be applied to other clinical, commercial and residential buildings to study the effect of the building policies on the traffic pattern and on the elevator congestion. Thus, it can provide future researchers with a flexible and robust test-bed to experiment research ideas concerning elevators. For our current study, we have calibrated the simulation model parameters by using data from Diamond Clinic, which is a multi-clinic facility of the Vancouver's general hospital. There exists 56 clinics in the Diamond clinic, located at floors 1-9, and there exists 5 elevators in service. On average, 1500 people enter the building lobby daily, where more than 300 patients arrive during the first hour of the day.

3 CCONTRIBUTION AND RESULTS

We show theoretically that the problem of optimally scheduling the clinics in a multi-clinic facility is equivalent to the bin-packing problem, and thus is NP hard. We prove theoretically that it is optimal to start the clinics located at the same or adjacent floors together. Moreover, we show theoretically that it is optimal to divide the arriving patients at the lobby between the available idle elevators (with the help of a "queue manager"), such that patients travelling to the adjacent floors board on the same elevator at the lobby. This motivates a dynamic zoning policy, in which elevators are dynamically assigned to serve different zones of the buildings throughout the day (e.g., one elevator to serve floors 1-4, and another one to serve floors 5-9 during the first hour). The insight behind these theoretical results is that if patients travelling to the adjacent floors board on the same elevator, then the elevator-round trip times will be minimized.

The above results facilitates finding an optimal scheduling because once the start time of a clinic is found, the start time of its adjacent clinics will also be found. However, the problem of optimally finding the adjacent floors of a given floor is still a hard problem. Thus far, we have examined the simple greedy policy for dividing the building floors into several adjacency groups, where an adjacency group comprises of clinics located at the consecutive floors and start at the same time. In the greedy policy, we group every C clinics together so that they can be serviced by a single elevator round-trip. We compared the total wait time associated with the greedy version of our proposed method to a sample schedule currently used in the Diamond clinic. Simulation results show that the greedy policy reduced the total wait time of patients for an elevator by 13-21%, depending on the number of people visiting the clinic on a given day (the reduction in wait time is higher in busier days). As the next step of this research, we will developing an approximation algorithm that can effectively divide a clinic building into optimal adjacency subsets.

REFERENCES

Dagdelen, U., A. Bagis, and D. Karaboga. 2005. "An Efficient Control Method for Elevator Group Control System". In *Proceedings of Computational Intelligence and Security*, December 15th-19th, Berlin, Germany, 1042-1047.