Moving More With Less: Examining the Efficiency of the TWIN Elevator System in the CODA building

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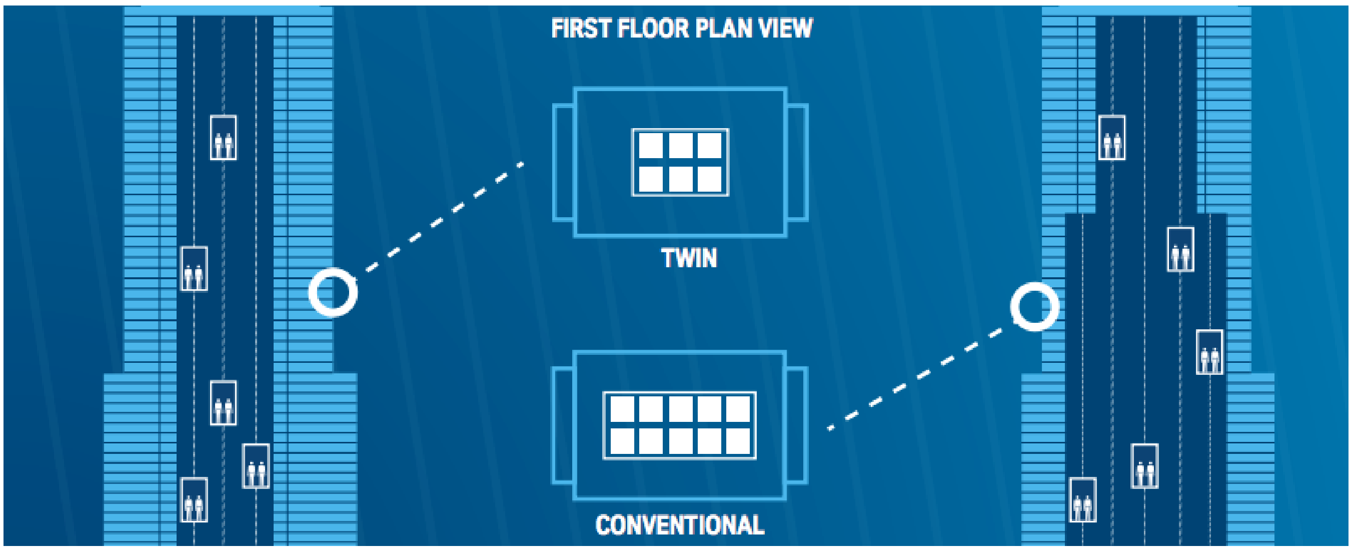

Figure 1: Example of a double cab lift system

ABSTRACT

1 INTRODUCTION

The boom in finance and technology services have seen companies and institutions cluster together in limited physical space, increasing the premium placed on land space, and with it, a rapid growth in the number of high rise buildings [2]. Moving people in high rise buildings however, remains relatively inefficient as determining the order in which to ferry people is a NP-Complete problem [4]. Multiple solutions exist to alleviate the situations, for example, introducing express elevators and skylobbies [5] or by using double-deck cabs that stop at two floors simultaneously [3]. The TWIN system by ThyssenKrupp however, utilizes two independent cabs in each elevator shaft and is advertised as being more efficient than traditional systems, both in terms of energy consumption and user throughput [6].

2 PROBLEM DESCRIPTION

The TWIN elevator differs from traditional elevator systems by having two cabs in one elevator shaft. These two cabs are completely independent and can move in different directions simultaneously. The system also uses a dispatch system where users' destinations are selected before entering the elevator. Designing the system thus consist of answering the following two questions

(1) How does the system assign an elevator to a user?
(2) How does the system account for a lift at maximum capacity?
(3) What is the operating range of each elevator cab?

such that

(1) Throughput of users is maximized
(2) Average waiting time is minimized
(3) Average time spent in the lift is minimized.

The system is also subjected to the constraint where cabs have no means of passing through each other. Thus the upper cab always remains on top of the lower cab, with the upper cab unable to reach the lowest floor and the lower cab unable to reach the highest floor. This project will be focused on answering the 1st question, while modelling the 2nd and 3rd questions after the existing system.

Furthermore, stochastic elements exist within this problem as the arrival of users, as well as their destination, is of a random nature. Thus, determining an optimal algorithm for this system remains complex and in such a situation, a Discrete Event Simulator (DES) provides better insights as it mimics real world situations. This can be seen as an extension of using DES to model traditional elevator systems [1].

3 TWIN ELEVATOR SYSTEM

The system used for this project is based on the existing system used in the CODA building in Atlanta. This consists of 21 floors and 6 elevator shafts for a total of 12 cabs. Each floor will be modelled by a random generator that generates users with random destinations, and a queue for the lift, as illustrated in Figure 2. The arrival of a user in the queue is an event that will trigger the assignment of a lift. Each lift can only be assigned when it is completely unoccupied.

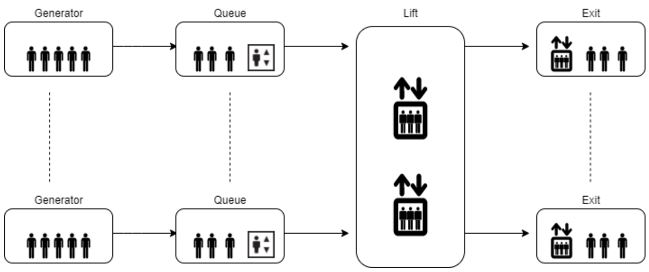

Figure 2: Conceptual model of the TWIN elevator system

4 TEST SCENARIOS

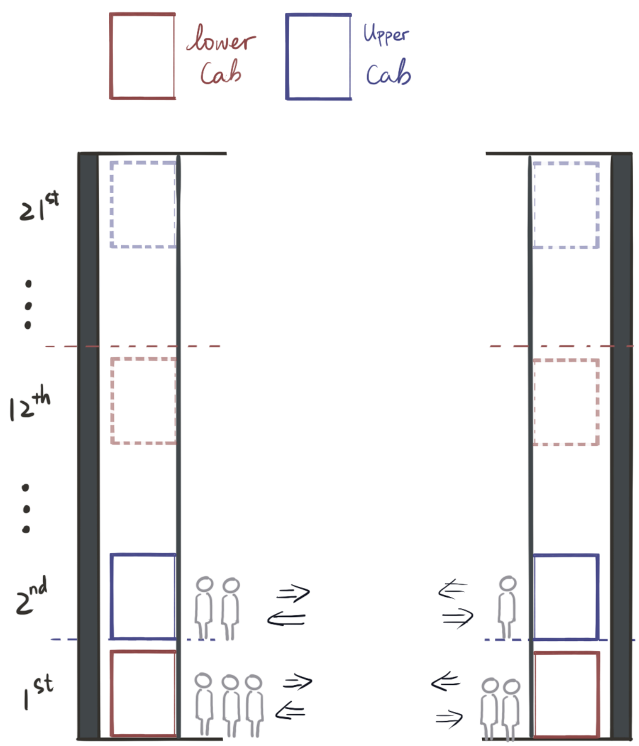

Figure 3: Conceptual diagram of the TWIN elevator system

The test scenarios are also modeled after the existing elevators in the CODA building and thus have limited operating range to reduce the complexity of the system. The lower cab will be limited to floors 1 to 12, while the upper cab will be limited to floors 2 to 21. This can be seen in Figure 3. A special scenario exists when users depart from either the 1st or 2nd floor. From the 1st floor, users can only reach floors 3 to 12. Users who wish to reach floors 13 to 21 must take the escalator to the 2nd floor first before riding the elevator. Any elevator currently bringing users to their destinations are considered as unavailable and will not be dispatched. Thus, no elevators will be stopped midway. Any elevators en route to pick a user up is also considered unavailable unless the users are already on the same floor. We will experiment with different limits on the number of stops an elevator can make.

Table 1: State Variables in Model

Variable	Value
La	Current Location
D	Destination
L’	Location of the Lower Cab
U’	Location of the Upper Cab
L	Lower Cab
U	Upper Cab

For this project, we will be testing two different algorithms for assigning an elevator to a user.

(1) This algorithm is based on a greedy paradigm, where the least utilized lift cab will be assigned. This means that the system will first search for the closest cab in a shaft where both cabs available. If all shafts have at least one cab in use, then the closest cab that is able to serve the user’s destination is assigned. Finally, if all cabs are in use, the cab with a final destination closest to the user will be assigned.
(2) This algorithm builds on the first scenario by taking into account the destination of the user and is run independently on each elevator shaft. The distance from the selected cab from each shafts to the user is then calculated and the nearest selected cab is assigned.
   (a) If no cabs are available, the user cannot use an elevator from this shaft.
   (b) If the user is on the 1st floor, the user must use the lower cab.
   (c) If the user is on the 2nd floor, the user must use the upper cab to go above the 13th floor.
   (d) If the user is above the 2nd and is above both the upper cab and the lower cab. The user will take the upper cab as seen in 4A.
   (e) If the user is in between both cabs as seen in Figure 4B:
      (i) If the user is between the 3rd floor and 12th floor, and the destination is between the 2nd and 12th floor, the user will take the closest cab.
      (ii) If the user is above the 12th floor, the user will take the upper cab.
      (iii) If the user is above the 2nd floor and the destination is above the 12th floor, the user will take the upper cab.
   (f) If the user is below both cabs as seen in Fig.4C:
      (i) If the user is below the 13th floor, the user will take the lower cab
      (ii) If the user is above than 12th floor, the user will take the upper cab.

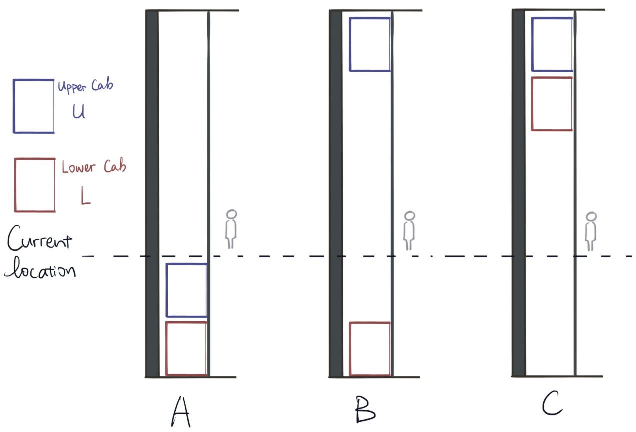

Figure 4: Test scenario

Algorithm 1 Elevator Assignment: Greedy-Improved Algorithm

```
function AssignElevatorCab(La, D, L′, U′, U, L)
    Cab ← ∅
    if La == 1 or D == 1 then
        Cab ← L
    end if
    if La == 2 then
        Cab ← U
    end if
    if L' < U' < La then
        Cab ← U
    end if
    if L' < La < U' then
        if La <=12 and D <= 12 then
            Cab ← ClosestCab
        else
            Cab ← U
        end if
    end if
    if La < L'< U' then
        if La <= 12 then
            Cab ← L
        else
            Cab ← U
        end if
    end if
    return Elevator
end function
```

5 DATA COLLECTION

Data needs to be collected for the two stochastic elements, the user interarrival rate and the user's destination. We will attempt to get the data directly from the CODA management or from ThyssenKrupp themselves. Should they not releast the information to us, we will conduct a physical survey in the building to determine the interarrival rate. We will conduct a personal survey of users to determine the distribution of user's destination.

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