The Impact of Elevator Control Strategies

REDUCTION OF THE NUMBER OF REQUIRED ELEVATORS

JOEL EKMAN AND TOM JOHANSSON
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Abstract

Elevator control strategies is a well studied field, where a lot of effort has been put in to developing efficient strategy that minimize the waiting and travel time. The purpose of this paper is to examine how two different versions of Collective Operation perform. The objective is to determine if it is possible to reduce the number of elevators required while still maintaining the requirement that the average waiting time do not exceed 30 seconds.

To carry out the study, a program that simulates an office building with eight floors has been developed. The program simulates the performance of the two strategies with one to eight elevators. A Poisson distribution of the incoming, interfloor, and outgoing traffic has been created based on data supplied by Peters Research. An improved elevator control strategy was found to be able to maintain the performance of the system, even though the number of elevators in the elevator group were reduced.

Keywords: Elevator, Elevator Control, Elevator Control Strategy, Elevator Group, Simulation, Office Building, Poisson Distribution
Sammanfattning

Hisskontrollstrategier är ett väl utforskat område, där mycket resurser spenderats på att utveckla effektiva strategier som minimerar väntetiden och restiden. Syftet med denna rapport är att undersöka hur två olika versioner av *Collective Operation* presterar. Målet med denna rapport är att avgöra om det är möjligt att minska antalet hissar som behövs med kravet att den genomsnittliga väntetiden inte överstiger 30 sekunder.

För att kunna genomföra studien har ett program som simulerar en kontorsbyggnad med åtta väningar utvecklats. Programmet simulerar och beräknar prestandan för de två strategierna med en till åtta hissar. En Poissonfördelning av inkommande, inom kontoret och utgående trafik har skapats baserat på data som erhållits från Peters Research. En förbättrad hisskontrollstrategi visade sig kunna bibehålla systemets prestanda samtidigt som antalet hissar i hissgruppen minskats.

Sökord: Hiss, Hisskontroll, Hisskontrollstrategi, Hissgrupp, Simulation, Kontorsbyggnad, Poissonfördelning
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1 Introduction

When buildings become taller, the need for efficient vertical transportation became essential to make the buildings fully accessible. In the pursuit of more efficient vertical transportation, the development of elevator control strategies has become an important field of study. A number of studies have been carried out in the field of elevator control strategies with the goal to minimize the waiting and travel time. This has proven to be difficult and the elevator scheduling problem is NP-hard [1].

An obvious way to increase the capacity of the vertical transportation in a building is to add more elevators. This has some drawbacks. For instance, more elevators take up more space, it makes the system more complicated, and it is more likely to confuse the passengers. These drawbacks makes it important to use the elevators as efficiently as possible, so that the number of required elevators can be minimized.

1.1 Objective

This paper will study office buildings with one or more elevators and examine the effect of implementing reallocation of landing calls when using the collective operation elevator control strategy. This means that the landing calls can be reallocated between the cars in the elevator group until one of the cars arrives at the floor of the landing call and answer it.

The study will compare the result from two different elevator control strategies, focusing on the travel and waiting time for the passengers using the system. The goal is to research and try to minimize the number of elevator cars required for achieving acceptable average waiting time.

1.2 Problem Statement

The problem consist of minimizing the waiting and travel time for elevators in an office building to reduce the number of required elevators.

1. Will the reallocation strategy reduce the average waiting time compared to the none-reallocation strategy?

2. Will the reallocation strategy reduce the average travel time compared to the none-reallocation strategy?

3. Will the reallocation strategy reduce the number of elevator cars required in the building compared to the none-reallocation strategy?
2 Background

2.1 Definitions

The key terms that will be referred to in the paper are defined below:

**Elevator Group**: is a group of elevators located in the same area working together to handle the landing calls.

**Incoming Traffic**: is when the majority of passengers arrive at the entrance floor and are waiting for transportation to the upper floors.

**Outgoing Traffic**: is when the majority of passengers are waiting for transportation from the upper floors to the entrance floor.

**Interfloor Traffic**: is when passengers travel between floors inside the building (entrance floors excluded).

**Light Traffic**: is when the number of passengers riding or waiting for transportation at a given time is less than the number of elevators in the group.

**Moderate Traffic**: is when the number of passengers riding or waiting for transportation at a given time is such that elevators in a group must be shared between passengers and all elevator use less than 50% of their capacity.

**Heavy Traffic**: is when the number of passengers riding or waiting for transportation at a given time is such that the elevators must be shared among many passengers and priority has to be giving to passengers traveling in one direction over those waiting for transportation in the opposite direction.

**Landing Calls**: a call for the elevator made from the panel located outside the elevator.

**Car Calls**: a call made for a floor from the panel inside the elevator car.

2.2 User Experience

To achieve a good user experience, it is important to not have too many elevators in a group, so that the passengers do not need to run between arriving elevators to find an elevator with capacity left. The maximum number of elevators in a functioning group consists of eight elevators. If the group consist of more than eight elevators their is a risk that arriving passengers will block the way for departing passengers [2].

It is important that the waiting time does not exceed 30 seconds to keep passenger satisfaction high, because in commercial environment the passengers will be impatient after 30 seconds of waiting [3].
2.3 Traffic Patterns

There are three different traffic patterns that occur in an office building. The traffic patterns have different characteristics and occurs at different times during the day. Each traffic pattern are described below.

2.3.1 Incoming Traffic

Incoming traffic normally takes place in the morning when the employees arrive at the office. This traffic pattern represents one of the heaviest traffic loads in an office building [4]. During incoming traffic, an elevator trip can be divided into eight different phases:

1. Load the passengers at the entrance floor
2. Close the doors and travel to the next stop
3. Open the doors and unload part of the passenger load
4. Repeat step 2 to 3 until the highest stop is reached
5. Close the doors and travel to the next stop in downwards direction
6. Open the doors and unload part of the passenger load
7. Repeat step 5 and 6 until entrance floor is reached
8. Open the doors and unload the passengers

Step one until eight will be repeated as long as the incoming traffic persists [5].

2.3.2 Outgoing Traffic

Outgoing traffic normally occurs at the end of the day, before lunch or in an emergency when the building needs to be evacuated. Heavy out traffic peaks may exceed any other traffic peak with 40 to 50 percent [6].

Outgoing traffic pattern do not resemble incoming traffic. Even if the fact that the traffic is going in the opposite direction is not taken into account, the two traffic patterns still do not have much in common. A major difference is that incoming traffic has one departure floor and several destination floors, while outgoing traffic has several departure floors and one destination floor [7].
2.4 Destination Time

Destination time is the complete time for an elevator trip. It is the time between the passenger call for the elevator until the passenger arrive at the destination floor. It can be divided into different parts, each part represents different states of the trip. The different parts are described below:

**Waiting Time:** is the time from when the landing call button is pressed until the elevator arrives at the floor and opens the doors.

**Dwell-time:** is the time the doors remain open at a stop. This time varies depending on how many passengers are being transferred.

**Transfer Time:** is the time it take to either load, unload or reload the elevator at a stop. It depends on the door opening time, the dwell time, and the door closing time.

**Running Time:** is the actual time when the car is moving at constant speed.

**Acceleration Time:** is the time it takes for the elevator to reach constant speed from standing still.

**Deceleration Time:** is the time it takes for the elevator to slow down from constant speed to standing still.

**Stop time:** is the time it takes to make a stop. It consists of the deceleration time, the transfer time, and the acceleration time.

**Door opening Time:** is the time it takes to open the doors.

**Door closing time:** is the time it takes to close the doors.

**Destination Time:** is the complete time for an elevator trip including waiting time, stop time, and running time.

2.5 Control Strategies

Many control strategies have been developed throughout the years. This section will give a brief description of the fundamental strategies and give some insight in the concepts of the more advanced strategies.

2.5.1 Collective Operation

Collective operation is one of the most basic strategies. It remembers all the calls and answers all calls in one direction then changes traveling direction and answer all calls in the opposite direction.

A version of collective operation is the well established selective collective operation. This version has landing call buttons with direction. Except from car calls the elevator will only stop for landing calls in the travel direction, other calls will be answered by the first elevator traveling in the right direction [8]. In this paper, collective operation and selective operation will be used interchangeable.
2.5.2 Modern Strategies

Today, most elevator control strategies utilize some form of machine learning or statistical prediction. This is used to predict the traffic pattern and adapt the elevator control strategy after the demand. During light to moderate traffic this can help reduce the travel and waiting time by predicting and positioning the elevators for a landing call before the call is registered. During heavy traffic there is less time for the type of optimization that machine learning allows and the impact on waiting and travel time is less noticeable [9].

2.5.3 State of the Art

The state of the art in elevator control strategies is hard to explore. Elevators are closed systems and the algorithms are industry secrets. Many of the large elevator companies often states that they use state of the art technology for marketing purposes, without releasing any detail on their algorithms [10][11][12]. The algorithms are kept secret to get a competitive advantage towards their competitors [13].

3 Method

3.1 Simulation

In order to be able to research the problem statements, an elevator system simulation was developed. The method of developing a simulation was chosen because its ability to compare the elevator control strategies with the same test data. It also made it possible to scale the simulation to test the strategies with various numbers of elevators.

The simulation works in iterations where one iteration represents one elapsed second which is the smallest time unit in the system. The reason to implement iterations is to be able to compare the strategy’s efficiency without having to take the performance of the simulation into account.

The simulation was written in the program language Java and the architecture is single threaded to avoid data-races and uneven time allocation that could interfere with the test results. All the main components are described in the sections below.

3.1.1 Central system

The central system is the hub of the elevator system simulation. It starts with initializing the other components in the system. After the setup it handles the iteration throughout the simulation and communicates with all the elevators in the system.
3.1.2 Iteration

The simulation uses iteration to carry out all the operation in the system one by one. An iteration represents one elapsed second. The iteration consists of three operations:

1. Register new landing calls in both directions

2. Set/update next stop for all the elevators according to the strategy

3. Update the state for all elevators

3.1.3 Elevators

The elevators in the simulation are specified according to the table below.

<table>
<thead>
<tr>
<th>Elevator specifications</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed:</td>
<td>400 fpm</td>
</tr>
<tr>
<td>Doors:</td>
<td>1200 mm center opening</td>
</tr>
<tr>
<td>Floor height:</td>
<td>3 m / 10 feet</td>
</tr>
<tr>
<td>Door operating time (open):</td>
<td>2 s</td>
</tr>
<tr>
<td>Door operating time (close):</td>
<td>3 s</td>
</tr>
<tr>
<td>Travel one floor:</td>
<td>5 s</td>
</tr>
<tr>
<td>Acceleration:</td>
<td>1 s</td>
</tr>
<tr>
<td>Deceleration:</td>
<td>1 s</td>
</tr>
<tr>
<td>Car call dwell time:</td>
<td>3 s per stop</td>
</tr>
<tr>
<td>Car call transfer time:</td>
<td>additional 1 s per 2 person after the first 2 passengers</td>
</tr>
<tr>
<td>Landing call dwell time:</td>
<td>5 s</td>
</tr>
<tr>
<td>Landing call transfer time:</td>
<td>additional 1 s per passenger after the first passengers</td>
</tr>
</tbody>
</table>

Figure 3.1: The specification of the elevators used in the simulation.

Each elevator iterates between ten states in the simulation. The different states are listed below:

State 0: The elevator is standing still with the doors closed.

State 1: The elevator is moving in either up- or downwards direction. If the elevator has arrived at a new floor it will check if this floor is the next floor it should stop at.

State 2: The elevator is decelerating to stop at the next floor.

State 3: The elevator has stopped at the floor of the next stop.

State 4: The elevator opens the doors.

State 5: Determine if their are passengers to unload.

State 6: Passengers are unloaded from the elevator.
State 7: Determine if their are passengers to load.
State 8: Passengers are loaded into the elevator.
State 9: The elevator closes the doors.
Figure 3.2: Flowchart describing the flow between the states of the elevator.
3.1.4 Passenger

The passenger simulates a user that travels with an elevator in the simulation. A passenger makes a trip from one floor to another floor. The trip consists of six actions made by the passenger. These actions are listed below:

1. Make a landing call at the departure floor
2. Wait for the elevator to arrive at the departure floor
3. Get into the elevator
4. Make a car call for the destination floor
5. Travels with the elevator
6. Get out of the elevator when the destination floor is reached.

The passenger also registers the total waiting time and the total travel time. This is used to evaluate different strategies.

3.1.5 Strategy

The strategy has one important function, to determine the next stop for the elevators. To achieve this, the strategy needs to be able to handle car and landing calls. The car call implementation is straightforward, it sets the next stop of the elevator to the next car call in the direction of the elevator's movement. If there are no car calls in that direction the elevator checks the opposite direction and responds to those calls. If there are no calls the elevator is set to idle.

For landing calls, the strategy becomes more important when assigning the right elevator to respond to a landing call. The process of assigning the landing calls depend on which strategy that is used.

3.1.6 Landing Call

A landing call consists of a calling floor, a list of calling passengers and the direction of the call. The landing call can be assigned to an elevator that should respond to it.

3.1.7 Car Call

A car call is created when a passenger enters the elevator car. The car call consists of a destination floor, the elevator it belongs to, and the passengers that made that call. The elevator will always stop at every car call it receives.
3.2 Strategies

The strategies used in the simulation are versions of *Collective Operation*. We refer to the reassigning version as *Collective Operation Continuous Allocation* and *Continuous Allocation* interchangeably and the none-reassigning strategy as *Collective Operation Single Allocation* and *Single Allocation* interchangeably. In both strategies, the elevators travels in one direction responding to car and landing calls in that direction. When there are no longer any calls in the elevators travel direction it reverse and respond to calls in the other direction. If all calls are answered the elevator is set to idle.

Both strategies use the same algorithm to determine which elevator to assign the incoming landing calls to. They are both greedy and always try to assign the best elevator possible at the time. The best possible elevator is the nearest elevator with loading capacity left, idling or traveling in the direction of the call. The differences between them are when they assign the landing calls, *Collective Operation Single Allocation* assign a call to an elevator when the call is registered. *Collective Operation Continuous Allocation* reassigns the landing calls at each iteration to always assign the call to the most suitable elevator at the time. This makes *Continuous Allocation* to a greedy algorithm that constantly try to improve the elevator assignments.

3.3 Test Data

The normal traffic pattern, which means the rate the passengers arrive at different floors, can be assumed to be Poisson distributed [7]. The traffic pattern varies throughout the day, but tend to have the same pattern day by day [9].

The test data is generated through a Poisson distribution based on data supplied by Peters Research, the developers of the worldwide industry standard traffic analysis software [14][15]. The data supplied is from an eight storey office building with 50 persons on each floor and starts at 07:00 and goes on until 19:15. The data consists of a timestamp, departure floor and destination floor for each trip.

According to the data there where 2316 trips in total during the day. The data was divided into 754 incoming, 781 interfloor, and 781 outgoing trips. For each traffic pattern the data was grouped into 5 minute intervals. To generate a work week of test data the number of trips made during each interval for each traffic pattern where used as mean value in the Poisson distributions. Both strategies where tested with the same data to not get ambiguous results.
Figure 3.3: Distribution of incoming traffic.

Figure 3.4: Distribution of interfloor traffic.
Figure 3.5: Distribution of outgoing traffic.

Figure 3.6: Distribution of incoming, interfloor, and outgoing traffic.
The results from the elevator simulation represents five working days of traffic in an eight floor office building. The result compares the two elevator control strategies *Collective Operation Single Allocation* and *Collective Operation Continuous Allocation*, with one to eight elevators.

Figure 3.7: Traffic distributions of incoming, interfloor, and outgoing traffic stacked together.

### 4 Result

The results from the elevator simulation represents five working days of traffic in an eight floor office building. The result compares the two elevator control strategies *Collective Operation Single Allocation* and *Collective Operation Continuous Allocation*, with one to eight elevators.
4.1 Terminology

**Number of Stops for All Passengers:** Each time an elevator stops to load or unload a passenger, the number of stops for all passengers in the elevator is increased by one. The result shows the sum of stops for all passengers.

**Average Waiting Time:** This is the average time the passenger waits for the elevator. It is measured from when the landing call is registered and until the passenger enters the elevator.

**Average Travel Time:** This is the average time the passenger spends in the elevator.

**Average Waiting and Travel Time:** This is the sum of the average waiting time and the average travel time.

4.2 Simulation Result

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Number of Elevators</th>
<th>Number of Stops for All Passengers</th>
<th>Average Waiting Time (seconds)</th>
<th>Average Travel Time (seconds)</th>
<th>Average Waiting and Travel Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>1</td>
<td>33,306</td>
<td>583.86</td>
<td>58.88</td>
<td>642.75</td>
</tr>
<tr>
<td>Continuous</td>
<td>1</td>
<td>39,101</td>
<td>480.8</td>
<td>64.92</td>
<td>545.72</td>
</tr>
<tr>
<td>Single</td>
<td>2</td>
<td>26,020</td>
<td>147.37</td>
<td>48.08</td>
<td>195.45</td>
</tr>
<tr>
<td>Continuous</td>
<td>2</td>
<td>29,470</td>
<td>57.46</td>
<td>51.25</td>
<td>108.7</td>
</tr>
<tr>
<td>Single</td>
<td>3</td>
<td>22,196</td>
<td>77.55</td>
<td>43.37</td>
<td>120.92</td>
</tr>
<tr>
<td>Continuous</td>
<td>3</td>
<td>23,809</td>
<td>28.52</td>
<td>44.82</td>
<td>73.34</td>
</tr>
<tr>
<td>Single</td>
<td>4</td>
<td>19,924</td>
<td>41.03</td>
<td>40.77</td>
<td>81.8</td>
</tr>
<tr>
<td>Continuous</td>
<td>4</td>
<td>20,538</td>
<td>18.77</td>
<td>41.6</td>
<td>60.37</td>
</tr>
<tr>
<td>Single</td>
<td>5</td>
<td>18,625</td>
<td>28.3</td>
<td>39.4</td>
<td>67.7</td>
</tr>
<tr>
<td>Continuous</td>
<td>5</td>
<td>19,466</td>
<td>14.91</td>
<td>40.2</td>
<td>55.1</td>
</tr>
<tr>
<td>Single</td>
<td>6</td>
<td>18,069</td>
<td>22.16</td>
<td>38.84</td>
<td>61.01</td>
</tr>
<tr>
<td>Continuous</td>
<td>6</td>
<td>18,715</td>
<td>12.89</td>
<td>39.49</td>
<td>52.38</td>
</tr>
<tr>
<td>Single</td>
<td>7</td>
<td>17,724</td>
<td>18.5</td>
<td>38.5</td>
<td>57</td>
</tr>
<tr>
<td>Continuous</td>
<td>7</td>
<td>18,460</td>
<td>11.98</td>
<td>39.24</td>
<td>51.23</td>
</tr>
<tr>
<td>Single</td>
<td>8</td>
<td>17,552</td>
<td>17.51</td>
<td>38.34</td>
<td>55.85</td>
</tr>
<tr>
<td>Continuous</td>
<td>8</td>
<td>18,269</td>
<td>11.31</td>
<td>39.06</td>
<td>50.37</td>
</tr>
</tbody>
</table>

Figure 4.1: Result from the simulation showing how the two strategies performs with one to eight elevators.
<table>
<thead>
<tr>
<th>Number of Elevators</th>
<th>Change in Average Waiting Time (seconds)</th>
<th>Change in Average Waiting Time (percent)</th>
<th>Change in Average Travel Time (seconds)</th>
<th>Change in Average Travel Time (percent)</th>
<th>Change in Average Waiting + Average Travel Time (seconds)</th>
<th>Change in Average Waiting + Average Travel Time (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-103.07</td>
<td>-17.65</td>
<td>6.04</td>
<td>10.25</td>
<td>-97.03</td>
<td>-15.1</td>
</tr>
<tr>
<td>2</td>
<td>-89.91</td>
<td>-61.01</td>
<td>3.16</td>
<td>6.58</td>
<td>-86.75</td>
<td>-44.38</td>
</tr>
<tr>
<td>3</td>
<td>-49.03</td>
<td>-63.22</td>
<td>1.45</td>
<td>3.34</td>
<td>-47.58</td>
<td>-29.35</td>
</tr>
<tr>
<td>4</td>
<td>-22.26</td>
<td>-54.25</td>
<td>0.8</td>
<td>2.05</td>
<td>-21.42</td>
<td>-26.19</td>
</tr>
<tr>
<td>5</td>
<td>-13.39</td>
<td>-47.33</td>
<td>0.8</td>
<td>2.02</td>
<td>-12.6</td>
<td>-18.61</td>
</tr>
<tr>
<td>6</td>
<td>-9.27</td>
<td>-41.83</td>
<td>0.65</td>
<td>1.66</td>
<td>-8.62</td>
<td>-14.14</td>
</tr>
<tr>
<td>7</td>
<td>-6.52</td>
<td>-35.24</td>
<td>0.75</td>
<td>1.94</td>
<td>-5.77</td>
<td>-10.13</td>
</tr>
<tr>
<td>8</td>
<td>-6.21</td>
<td>-35.44</td>
<td>0.73</td>
<td>1.89</td>
<td>-5.48</td>
<td>-9.81</td>
</tr>
</tbody>
</table>

Figure 4.2: Result form the simulation showing how the two strategies performs in comparison with one to eight elevators.

![Average Waiting Time (5 work days)](image)

Figure 4.3: Average waiting time for the two different strategies with different numbers of elevators. The dashed line at the 30 second mark indicates the highest acceptable average waiting time in an office building.
Figure 4.4: Average travel time for the two different strategies with different numbers of elevators.

Figure 4.5: Average waiting and travel time for the two different strategies with one to eight elevators.


Figure 4.6: Number of Stops for all passengers.

5 Discussion

The test results clearly indicate that the change of elevator control strategy has a big impact on the destination time. As seen in figure 4.1 the Collective Operation Continuous Allocation has a better average destination time than Collective Operation Single Allocation.

5.1 Impact on Waiting Time

The Collective Operation Continuous Allocation drastically reduced the average waiting time compared to Collective Operation Single Allocation. This is a result of Continuous Allocation ability to reassign the landing calls to the best suited elevator until the landing call has been answered. This reduces the waiting time because a waiting passenger always travels with the first possible elevator and does not need to wait for the elevator that was most suited to answer the landing call when it was registered. In many situations the elevator that was first registered for the landing call will not be the first possible elevator to answer it. For example the first assigned elevator can have many stops to answer before reaching the landing call, so
in many cases another elevator will be able to arrive earlier.

The improvement in average waiting time when using *Continuous Allocation* instead of *Single Allocation* largely depends on the number of elevators in the group. Figure 4.2 shows the reduction in average waiting time when changing strategy for different number of elevators. With one elevator the reduction is below 20%, with two or three elevators more than 60%, with four or five elevators about 50%, with six elevators about 40%, and with seven or eight about 35%. This shows that the importance of the elevator strategy is reduced when the number of elevators is increased. It is clear that the reallocation strategy reduces the average waiting time.

### 5.2 Impact on Travel Time

As seen in figure 4.2 the *Collective Operation Single Allocation* average travel time is slightly lower than *Collective Operation Continuous Allocation*. This is due to the increased number of stops the elevator makes before all of the passengers reach their destinations when traveling with *Continuous Allocation*. This can be seen in figure 4.6. Each stop adds travel time for all passengers that travel with the elevator and this raises the total average travel time. This marginally makes the *Continuous Allocation* strategy less efficient than *Single Allocation* regarding average travel time. This is a minor concern because the difference in average travel time between the two strategies is small compared to the difference in average waiting time. The reallocation strategy will not reduce the average travel time compared to the non-reallocation strategy.

### 5.3 Impact on Destination Time

The result evidently shows that *Continuous Allocation* reduces the average destination time compared to *Collective Operation Single Allocation*. This is despite the fact that the average travel time is increased, the major reduction in waiting time more than compensates for the increased average travel time. The average destination time is reduced by 9.81% to 44.38% depending on the number of elevators in the group.

### 5.4 Impact on Number of Elevators

As seen in figure 4.3, to get an acceptable average waiting time (below 30 seconds) with *Collective Operation Single Allocation* five elevators is required according to the simulation. To get an acceptable average waiting time with *Collective Operation Continuous Allocation*, only three elevators is required.

The test result as displayed in figure 4.5 shows that a control strategy that continuously assigns landing calls such as *Continuous Allocation* can reduce the destination time (waiting time + travel time). With reduced destination time the elevators can efficiently serve more passengers. This
makes it possible to reduce the number of elevators required in a building while maintaining the average destination time. As seen in figure 4.5 a group with four elevators running Continuous Allocation has a lower average destination time than a group of six elevators running Single Allocation. The Continuous Allocation could in this case reduce the required number of elevators from six to four and reduce the average destination time.

The reduction of elevators has a big impact on useful space in the building. An elevator consumes space on all the floors throughout the building its shaft passes through. This space can be used in a better ways if the number of required elevators could be reduced. Reducing the number of elevators will increase the usability of the elevators because it is less confusing for the passenger to find the elevator they should travel with.

There are also a number of economic reasons to minimize the number of elevators. For example it is less expensive to purchase and install fewer elevators in the building.

5.5 Source of Error

The result is clear but the question remains if the result is correct. The result is largely dependent on how well the simulation simulate a real elevator system. The traffic flow data that is used to simulate the traffic flow in an office building can also have distorted the result.

The Collective Operation Continuous Allocation is not based on machine learning or state of the art tactics that the cutting edge strategies uses to improve their performance. The Continuous Allocation show proof of concept that elevator strategies are an important tool to improve the systems performance but it is not fully covered at which magnitude the best strategies of today would perform.

6 Conclusion

Returning to the questions in the problem statement, the research has shown that Continuous Allocation is more efficient than Single Allocation when considering waiting time. It is also more efficient regarding destination time, even though Single Allocation has shorter travel times. This is due to the fact that the average waiting time for Continuous Allocation was a remarkable improvement over Single Allocation.

The major improvement in efficiency made it possible to reduce the number of required elevators. By switching strategies from Single Allocation to Continuous Allocation, the number of required elevators in a group of six elevators could be reduced to four elevators without degrading the performance of the group. In this case, it is a 50 % performance boost per elevator when using the Collective Operation Continuous Allocation instead of Collective Operation Single Allocation.
References


