Investigation of an Elevator Call Strategy

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Abstract This paper attempts to describe the simulation of the lift call strategy used by a passenger lift within a university building. The purpose of this study is to devise and develop strategies to enhance the current lift operations by reducing the average waiting time of passengers. A base model was developed to mimic the actual lift system and different approaches were carried out to meet the project aims. The simulation was done by using WITNESS software. The lift is in high demand during the interchange of classes and also at lunch time. It was observed that the lift experienced heavier traffic in the time between 9:00AM and 1:00PM of the day. Passenger's traffic data was collected manually in that period. After analysing the data, four new lift call strategies were devised. All of the strategies were simulated and results were compared to base model. Among the strategies, the strategy that incorporated the car to wait at the unloaded floor appeared to produce the best results as it reduced the average waiting time by 4.4%.

Keywords Lift, Elevator, Witness, Simulation

1. Introduction

Passenger lifts are a mandatory requirement in buildings with multiple floors [1]. The primary function of a lift is to service passenger requests while optimising the overall service quality [2]. Passengers often experience lift congestion as a result of heavy traffic at peak times [3]. Waiting for a lift can be one of the main annoyances in the experience with high buildings [4]. Ways to improve the efficiency of lift transportation systems in public buildings has become a significant problem for practical applications [5], especially during the up-peak hours [6,7].

The project was inspired by a lift congestion problem in John Dalton East Building, Manchester Metropolitan University, Manchester, UK [8]. It was noticed that the lift (single car) in this building is in high demand during office hours, and has often resulted in long waiting time of passengers. Therefore, an efficient lift system was required to solve the problem. The project was aimed to simulate the current lift dispatching system and devise new strategies to

enhance the system.

At the early stage, research on available literature was done to study the background and concepts for different types of lift dispatching systems. To obtain realistic usage data, a survey was conducted to collect passenger traffic data. Following from this, new strategies were devised after analysing the data collected in order to produce an efficient lift dispatching system.

WITNESS simulation software [9] was chosen as a suitable tool to model and simulate the lift system. After an investigation and suitable data collection a base model was developed representing the current lift system. New strategies were applied to the model; their results were obtained and compared to determine the best strategy.

2. Objectives

To explore strategic changes to the lift call strategy which will reduce the average queue waiting times resulting in higher service levels for passengers. The new strategy is expected to minimize the queues of passengers formed due to the lift congestion problem.

3. Materials and Methods

3.1. Background

The study concentrates on the lift (Installation Number: MMU Lift 33) in John Dalton East Building. This building consists of 5 floors and houses the Faculty of Science and Engineering at Manchester Metropolitan University. During office hours, the lift is highly demanded, especially during the interchange of lecture classes and also lunch time (9:00AM – 1:00PM).

This is a single-car lift and it can carry up to a maximum of 13 passengers. The current strategy used by the lift is first-come first-serve basis and it does not have a special strategy to handle the peak hours. When the lift responds to a call, it will first look at the direction of travel. The lift will then respond to the nearest calls with the same direction of travel when it moves towards them and it will park at the

ground floor when there is no demand.

Students and staffs often use the lift to travel to different floors, but due to the long waiting time, some of the passengers decide to use the stairs. It can be argued that the lift is not serving its purpose efficiently. Therefore, it is necessary to devise a better strategy to tackle the lift congestion problem during the peak time.

3.2. Data Collection Method

In order to collect a set of realistic data, a field study was carried out. The passenger's traffic data was collected through observation inside the lift as well as at the floor call points. Data such as the arrival time of passengers was obtained at the call point on each floor. Whereas the source and destination of passengers was collected through observation inside the car.

It was observed that the lift experienced heavier traffic in the time between morning classes and lunch time (9:00AM – 1:00PM) of the day. Since the project aim is to tackle the lift congestion problem, therefore only data in the peak hours was collected. A survey was conducted to gather the usage of the lift.

3.3. Collected Data

3.3.1. Arrival Data

Table 1 shows the maximum arrivals of different passengers at each floor observed and tabulated during the up-peak.

Table 1. Maximum arrival of Passengers

Passenger	Maximum Arrivals	Passenger	Maximum Arrivals
G_1 st	3	Second_3 rd	1
G_2 nd	12	Second_4 th	3
G_3 rd	77	Third_G	50
G_4 th	74	Third_1 st	2
First_G	3	Third_2 nd	3
First_2 nd	1	Third_4 th	4
First_3 rd	4	Fourth_G	59
First_4 th	4	Fourth_1 st	8
Second_G	12	Fourth_2 nd	6
Second_1 st	1	Fourth_3 rd	6

3.3.2. Car Travelling Time

The travelling time of the car is needed to determine the car travelling speed in the simulation model. The duration of travel was timed using a stopwatch, the results are shown in table 2.

Table 2. Car Travelling Time

Floor	Time taken (second)
Ground Floor – 1 st Floor	5.27
1 st Floor – 2 nd Floor	5.10
2 nd Floor – 3 rd Floor	4.72
3 rd Floor – 4 th Floor	5.02
Average Value	5.03

From table 2, the computed average travelling time was used within the model.

3.3.3. Loading and Unloading Time

The loading and unloading time includes the opening and closing time of lift doors as well as the time for passengers to go in and get out from the lift. Again, the duration was timed using a stopwatch, results are shown in Table 3 and Table 4.

Table 3. Passenger loading time

Floor	Time taken (seconds)
Ground Floor	5.36
1 st Floor	4.63
2 nd Floor	4.72
3 rd Floor	4.91
4 th Floor	4.80
Average Value	4.884

Table 4. Passenger unloading time

Floor	Time taken (seconds)
Ground Floor	5.51
1 st Floor	4.52
2 nd Floor	4.70
3 rd Floor	4.89
4 th Floor	4.84
Average Value	4.892

As seen from tables 3 & 4, the average loading/unloading times are very similar which were used in the model.

3.4. Modelling

In order to obtain realistic results, the lift was modelled and run with the same strategy as it is. The model mimics the real life scenario where the lift has 5 stops and responds to passenger calls in first-come first-serve basis. Initially, the lift will look at the direction of travel and it will then respond to the nearest calls with the same direction of travel when it moves towards them. Since the lift experienced heavier traffic in the time between 9:00AM and 1:00PM, only data in those hours was applied to the model.

Figure 1. Arrival of passengers into model

3.4.1. WITNESS Elements

Modelling begins with the use of elements according to the requirements. Table 5 maps the WITNESS elements with the real life system.

Table 5. Mapping of Witness elements

Element	Names in model	Represents
Entity	G_1st, First_2 nd etc.	Passengers
Queue	Qin, Up, Down etc.	Waiting Points
Activity	Batch, Join, Sort etc.	Loading and Unloading Points
Track	Floor	Lift Shaft
Vehicle	Lift	Car

3.4.2. Modeling of Passengers

The WITNESS element Entity is used to represent the passengers who used the lift. Table 6 shows the color scheme used to differentiate the passenger's destinations.

Table 6. Identification of Passengers Destination

Icon	Represents
	Passengers travelling to Ground Floor
	Passengers travelling to 1 st Floor
	Passengers travelling to 2 nd Floor
	Passengers travelling to 3 rd Floor
	Passengers travelling to 4 th Floor

Figure 1 shows the details of model element G_{1st} which represent the passengers arrive at Ground Floor and travel to 1st Floor. Type is set to Active with Profile means the entities will be created according to the Arrival Profile as per data collected. The value of Maximum Arrivals is set to 3 following the data collected and Lot Size = 1 means one entity will be created at a time. Finally, *Actions on Create* determine the color of entities (PEN 1-5) according to their destinations and update the *Floor_Entries* counter values in the model.

4. Modelled System

Figure 2, illustrates the control strategy used in the base model. This strategy is first-come first-serve basis. The lift will load the first passenger and move in the desired direction. If there is a call with the same direction of travel, the lift will load the passenger as it moves towards that floor. With this strategy, the lift will always load and unload passengers at the nearest floor according to the direction of travel.

Figure 2. Flowchart of Base Model

Figure 3. Witness Base Model representing the lift system

4.1. Base Model

Figure 3 illustrates the Witness model constructed representing the lift system “as is” and described as the base model. It is suffice to state that verification and validation of the base model was completed. Further details of the Witness constructs and elements used to model the lift system are omitted in this paper as they are the subject of a future paper.

The graphics display of the base model has been developed with some KPI data as shown in figure 4 representing four hours of continuous simulation.

Statistical results obtained from this simulation are presented and discussed in the Results and Discussion

section.

Figure 4. KPI display of Base Model

4.2. Strategy 1

The concept of Strategy 1 is to always set the destination of lift in the ascending order of G – 1st – 2nd – 3rd – 4th Floor. By doing this, Ground Floor will always has the highest priority when the lift sets its destination. Similar to the base model, if there is a call with the same direction of travel, the lift will load the passenger as it moves towards that floor. The lift will then set a new destination using the same order. After unloading all passengers, the lift will park at the unload

track until a new call is made.

From the data collected in Table 1, it shows that most of the passengers came from the Ground Floor. The concept is to allow the lift get to Ground Floor as frequent as possible. This idea was aimed to increase the number of loadings at Ground Floor in order to reduce the waiting time.

4.2. Strategy 2

Strategy 2 is similar to Strategy 1 except the lift will park at 4th Floor when there is no call made.

Following Strategy 1, since Ground Floor has the highest priority when the lift sets its destination, this approach was to let the lift stand-by on 4th Floor in order to balance the number of loadings for higher floors. Strategy 2 is mainly aimed to enhance the Strategy 1 in terms of work distribution at different floors.

4.3. Strategy 3

Strategy 3 reversed the destination setting of Strategy 1 to descending order of 4th – 3rd – 2nd – 1st – G Floor. Besides that, similar to Strategy 1, the car will remain at the same floor after unloading all passengers.

Data collected in Table 1 shows that the second largest volume of the passengers was arriving from 4th Floor other

than Ground Floor. This strategy attempts to increase the number of stops at 4th Floor in order to pick up more passengers. Overall, Strategy 4 aims to reduce the waiting time on 4th Floor.

4.4. Strategy 4

The only difference between Strategy 3 and Strategy 4 is the car will park at Ground Floor when there is no call made in Strategy 4.

This approach was to balance the number of loadings at lower floors because 4th Floor has the highest priority when the lift sets its destination. The reason Strategy 4 was developed is mainly to focus on the waiting time at Ground Floor because it has the highest maximum arrivals of passengers as shown in Table 1.

5. Results

Table 8 and Table 9 summarize the average waiting time of passengers in queues and statistical results of the lift (vehicle) obtained from the base model and the four different strategies.

Table 8. Summary of average queue waiting time

Queue	Floor	Average waiting time (second)				
		Base Model	Strategy 1	Strategy 2	Strategy 3	Strategy 4
QIn(1)	Ground	88.10	90.34	90.34	88.10	88.10
UP(1)	First	125.46	101.71	101.71	125.46	125.46
DOWN(1)	First	26.44	26.44	26.44	39.10	39.10
UP(2)	Second	42.96	42.96	42.96	42.96	42.96
DOWN(2)	Second	99.46	99.46	99.46	84.82	84.82
UP(3)	Third	16.66	16.66	16.66	16.66	16.66
DOWN(3)	Third	86.31	86.31	86.31	78.71	78.71
Qin(5)	Fourth	21.47	21.47	21.47	31.15	31.15
	Average	60.67	57.99	57.99	59.48	59.48

From Table 8, it can be seen that Strategy 1 and Strategy 2 obtained a shorter average waiting time among all the strategies when compared to the base model.

Table 9. Lift statistics

	Base Model	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Free (%)	15.38	15.38	15.38	12.31	12.31
Loaded (%)	84.62	84.62	84.62	87.69	87.69
Distance Travelled (m)	305.00	305.00	324.00	305.00	305.00

Table 9 shows that Strategy 1 has a shorter travelled distance compared to Strategy 2. From table 9 it is evident that not all strategies managed to reduce the distance travelled by the car.

6. Discussions

Results obtained from all of the strategies show how well the strategies performed in terms of approaching the project objectives. An ideal lift call strategy is expected to provide shorter waiting time than the current system in order to solve the lift congestion problem. Reducing the average waiting time means minimizing the queue crowd formed at the lift. The strategy is also expected to have shorter travelling distance which can reduce the energy consumed by the lift.

Strategy 1 and Strategy 2 fulfill the project aims by reducing the average waiting time from 60.6s to 57.9s, which is 4.4%. However, Strategy 1 has a shorter travelling distance compared to Strategy 2, meaning that Strategy 1 is a better solution because it consumes less energy. Although Strategy 1 did not reduce the travelling distance of base model, but the strategy is able to reduce average waiting time which is the main objective of the project. The results demonstrate that by setting the destination of the car in the ascending order ($G - 1^{st} - 2^{nd} - 3^{rd} - 4^{th}$) this enables a reduction in the average waiting time experienced by passengers at the call points.

Strategy 3 and Strategy 4 can be said to be less successful. These strategies did not manage to reduce the average waiting time. There is no improvement shown in the *%Free* and *%Loaded* category for the lift.

7. Conclusion

The project is a success as the main objectives were achieved by the strategy developed. The survey conducted was able to provide realistic passenger's traffic data to drive the simulation model. The worst time scenario was simulated and different strategies were devised aiming to improve the situation. A total number of four new strategies were devised and tested in the simulation model. All the results obtained from different strategies were compared against the base model. Although some of the strategies did not fulfill the project aims, but useful knowledge was gained.

Strategy 1 is selected as the best solution because it is able to reduce the average waiting time from 60.67s to 57.99s (4.4%). Whilst a 4.4% reduction in the average waiting time may not seem to be significant the practical reality is often very different. Since the model is simulating the travelling experience of over 160 passengers then a reduction in the average waiting time of even 4.4% is well worth while adopting this change. Other than that, Strategy 1 remains the shortest travelling distance of the lift. Overall, the objectives of project were completed.

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