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Exploiting Witness to Simulate a Passenger Lift Call Strategy

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ABSTRACT

This paper reports on a project that simulates the behaviour of a passenger lift in the Manchester Metropolitan University (MMU) Law School building and aims to develop effective strategies so that the average waiting time of passengers could be reduced as well as reducing the distance travelled by the lift car. Site investigation is firstly carried out to observe the behaviour of lift, and to obtain lift usage data.

This project seeks to provide a more efficient and effective lift call strategy based on using WITNESS 13 simulation software. A base model representing the current installation was developed leading to a number of experiments designed to test different lift call strategies.

In comparison to the base model the improved strategic model is able to reduce the average passenger queue waiting time by nearly 15%. Unfortantly the reduction in the queue waiting time came at the expense of marginally increasing the distance travelled by the lift cars during the peak period. Overall the the project was deemed successful opening lots of scope for further scenario testing.

Indexing terms/Keywords

Elevator; discrete event simulation; dispatching strategy; Lift; Simulation; Witness.

1.0 INTRODUCTION

Passenger lifts are the crucial elements to access multi-floor buildings[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 one's experience with tall 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 the potential of a lift congestion problem in Manchester Metropolitan University (MMU) Law building on visitor open days [8]. It was noticed that the three lift cars servicing seven floors in this building were in high demand during office hours, and has often resulted in long waiting time of passengers especially during visitor open days. Therefore, an efficient lift call strategy 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. In order to obtain realistic results, a survey was conducted to collect passenger traffic data. Then, new strategies were devised after analysing the data collected in order to produce a realistic lift dispatching system.

WITNESS simulation software [9] was chosen as a suitable tool to model and simulate the lift system. After an investigation and 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.

2.0 DATA COLLECTION

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 outside the lift. Data such as the arrival time of passengers was obtained outside the lift on each floors. Whereas the origin and destination of passengers was collected through observation inside the lift.

It was observed that the lift experienced heavier traffic during the start of the morning classes (09:00-10:00 hrs). Since the project aim is to tackle the lift congestion problem, therefore only data in the peak hour was collected. A survey was conducted to gather the usage of the lift. Table 1 depicts the number of passengers at each floor call point during the survey.This data was analysed enabling some indication of the passenger floor movements.

Table 1. Arrival of passengers

Floors	Passengers Arrived
Ground	29
1st Floor	1
2nd Floor	7
3rd Floor	5
4th Floor	6
5th Floor	11
6th Floor	15

In addition to Table 1 observation data, it was also realisd that eighty visitors (open day) were expected per hour to use the lift system.

The car travelling time was recorded between floors and it was determined to be 8 seconds per floor. The door opening and closing times for the car was determined to be 2.6 seconds. It was deemed appropriate to only simulate the peak hour of operations.

3.0 MODELLING

The current lift system in the MMU Law School was modelled by using WITNESS simulation software. A base model was created to operate and behave like the real system through numerous validations and verifications. The lift system comprises of a bank of three cars. The current strategy is that one of the cars will always go to the ground floor whenever the other two cars are busy or parked at higher floor. Besides that, the three cars will usually park at Ground Floor, 2nd Floor and 5th Floor separately. If a lift call is made, the car at the floor nearest to the called floor will respond and go to the desired floor. For example, if there's a call made at 3rd floor, the nearest car stationed at the 2nd floor will respond and move towards 3rd floor, transporting the passengers to their desired floor. After unloading, the lift car will park at the respective floor governed by the position of the other cars.

3.1 Witness Elements

Different types of elements in WITNESS were used to build the base model. The elements like entity, queue, activity etc. were mapped and used to represent the real life system as shown in table 2.

Table 2: WITNESS elements representing real systems

Elements	Represents	Element Name
Entity	Passengers/ Visitors	G_Floor, Floor1, Floor2 etc
Activity	Loading and Unloading Process	Group, Joining, Splitting etc
Queue	Waiting Points	Qu, Going_Up, Going_Down etc
Vehicle	Lift cars	Car_1, Car_2, Car_3
Track	Building's Floors	Lift, Lift2, Lift 3

Witness elements known as entities were used to represent the passengers/visitors using the lift in the simulation model. Changing the colours of entities using the PEN system attribute differentiates floor passengers. Different destinations are represented with different colours. Table 3 depicts the relationship between entity colour and floors.

Table 3: Floors represented by different colours

PEN Code	Entities colour	Floors representing
1	Red	Ground Floor
2	Green	1st Floor
3	Yellow	2nd Floor
4	Blue	3rd Floor
5	Magenta	4th Floor
6	Cyan	5th Floor
7	White	6th Floor

Activity elements in WITNESS were used to perform tasks in order to complete an operation. Each entity will be processed by an activity and undergo several process before it has reached its destination. There are a few activities used in the simulation model such as Sorting, Grouping, Joining, Splitting and Decision that enable the entities to enter, ride and exit the lift car which is modelled as a batch process.

3.2 Sorting Activity

Sorting activity is used to separate those input entities (passengers) to their desired direction of either going up or down.

On top of the right hand corner in the figure 1 is the graphic element of an activity with its name. The detail form shows what is happening in an activity. There is an input rule which written as "PULL from Qu(1)", which mean the activity will pull an entity from the queue, then push it to another queue which are either Going_Down or Going_Up where the output rule is shown above. Note that there are five instead of seven sorting activities as the ground floor and highest floor does not require any decision making as their only choice would be going up and going down respectively.

Fig 1: Details of the Sorting activity

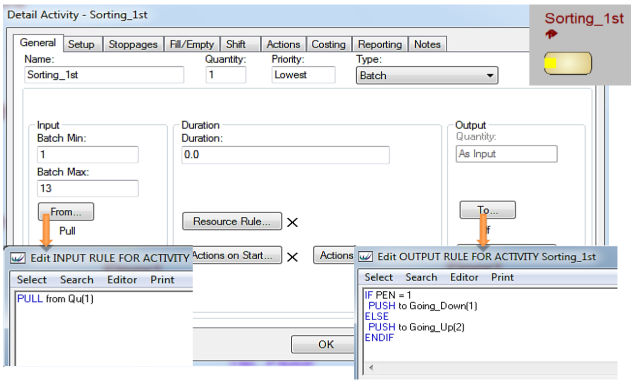
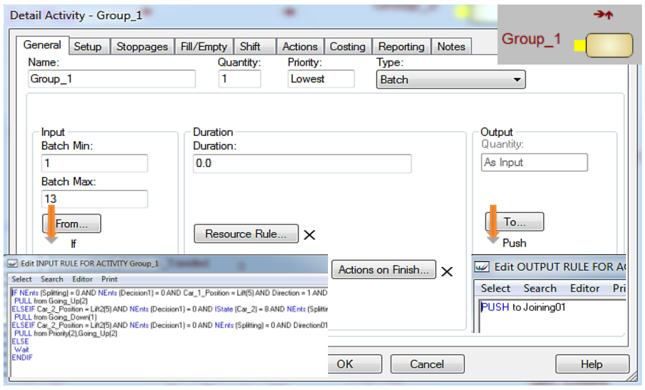


Fig 2: Details of Grouping Activity



3.3 Grouping Activity

The Grouping activity is used to pull entities from the queue, at the same time ensuring that the numbers of entities do not exceed 13 (physical capacity of the car).

The input rule of the grouping activity decides when to pull the entity from the queue. For example, if there is waiting entity (passenger) in the ground floor, it will first determine whether the car is at the ground floor. The entity will be pulled from the queue when a car has arrived at the ground floor, it will then pull all waiting entities in the queue but the number is limited to 13 as the lift has a maximum capacity of 13. This can be done by editing the input in detail activity where batch min= 1 and batch max = 13. After that, it will then push to joining activity.

3.4 Vehicle (Lift Cars)

A vehicle element in WITNESS were used to represent the lift cars in the real system.

Figure 3: Vehicle (No load)

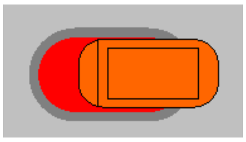


Figure 4: Vehicle (Loaded)

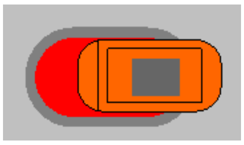


Figure 3 shows the graphic of vehicle on a track without any load whereas figure 4 is the vehicle on track with load. Below is the detail of how the vehicle is set to operate on a vertical track in the simulation model.

3.5 Track (Building's Floors)

Witness track elements represents the vertical lift shaft of the building and its floors.

Figure 5: Tracks

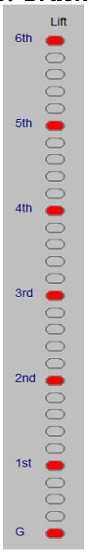


Figure 6: Details of track (General)

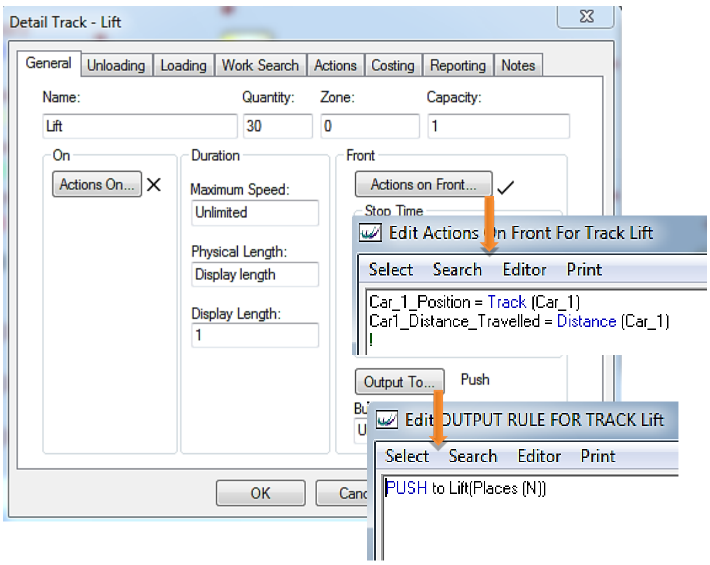
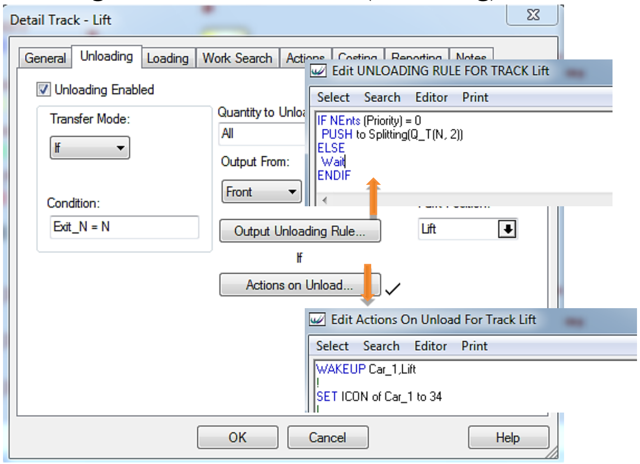


Figure 5 shows the graphic elements of the tracks used in the simulation model whereas figure 6 are the details of the track. The track quantity is set to be 30 in as it can be used to calculate the distance travel easily, therefore 30 divide by 5 is 6 different floors excluding the ground floor. The total distance travelled and the position of the car is shown by inserting the commands in figure 6 into the actions on front for track. The output rule for track is set to "PUSH to Lift(Places (N))" which mean the lift will continuously moving upwards to the top then move downwards until the bottom according to a function until there's a specific exit command.

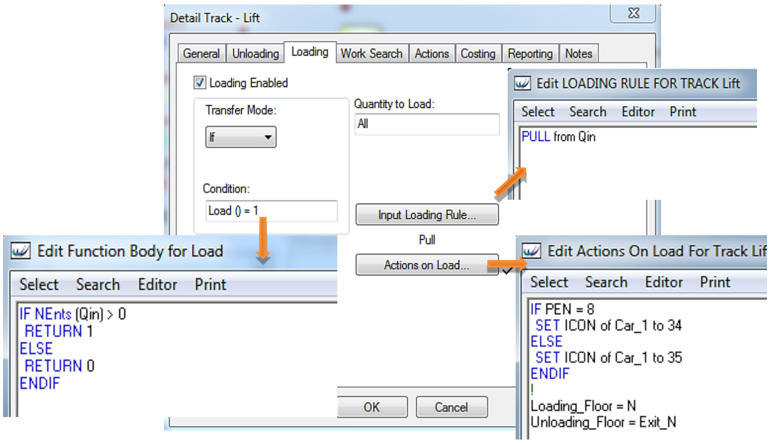
Unloading (figure 7) can only occur if the unload condition is met which is the exit floor of the entity has to match with the number of the floors. If Exit_1 = 1, then unloading happens. The output rule is set as push to splitting where the unloaded entity will be push to splitting activity accordingly. During the unloading time, the command WAKEUP is used to ensure that the car stays at the standby condition at all time.

Figure7: Details of Track (Unloading)



If the number of entity (passengers) in Qin is bigger than 0, the car loads the entity. This is the condition required in order to activate the loading action of the car. When the condition is met, car will pull the entity available on Qin. For example, Car_1 is set to always pull the entity from Qin while Car_2 will always pull the entity from Qin2. During the loading condition, Icon of Car will change to 35 (figure 4), then there will be two variables: Loading_Floor and Unloading_Floor to indicate the current loading floor of the car and where it is going to unload at.

Figure 8: Details of Track (Loading)



The logical operations for the base model are depictd in figure 9. The strategy used is that the lift car will always respond to the nearest call and attend to that floor. Besides that, during the free time, the 3 cars will park separately at different floors which is Ground, 2nd and 5th. Figure 10 depicts the Witness base model of the lift system.

Fig 9: Operational logic of the base model

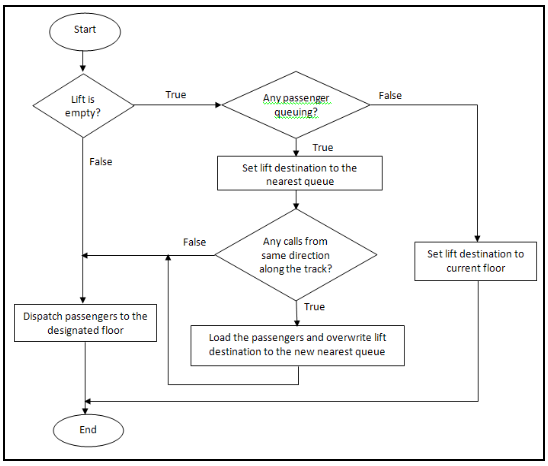
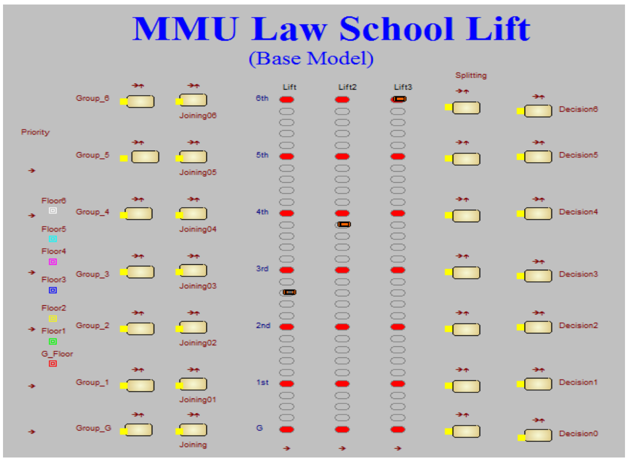


Fig 10: Witness model of the current lift system



4.0 EXPERIMENT

The base model is first completed and then tested with another two experiments which aim to reduce the waiting time and to balance the travelling distance of the lift cars. After that, a hybrid strategy 3 model is then built from the experiments made.

Base Model:

This is the lift model built according to the current lift system in MMU Law School and it works exactly the same as how the real lift system in MMU Law School works. The strategy used is that the lift car will always respond to the nearest call and attend to that floor. Besides that, during the free time, the 3 cars will park separately at different floors which is Ground, 2^{nd} and 5^{th}.

Strategy 1

To ensure the each car has a balanced travelling distance. This means a less travelled car will respond to the call. Secondly to ensure two of the lift cars will always go back to the ground floor after serving the passengers. It is designed due to the high demand at the ground floor during the peak hour.

Strategy 2

To respond to the call point that has the longest queue waiting time. This will mean the queue waiting time is likely to be reduced but the distance travelled for each car will not be balanced.

Strategy 3

This model combines the features of strategy 1 and 2 which results in the best strategy to improve the efficiency of the lift to work with the current data. By ensuring two lift cars return to ground floor more frequently and balance the distance travelled by 3 cars.

Result from the base model, three strategy models are obtained and analysed in order to make sure that the result obtained meet the objectives of this project were improvements compared to the base model are achievable. However for the sake of clarity results from base model and strategy 3 will be presented and compared.

5.0 RESULTS

It was deemed important to consider (1) average queue waiting time; (2) distance travelled by cart: (3) percentage of time the cart was loaded. These three key performance indicators (KPIs) are depicted in tables, 4,5 and 6.

Table 4. Average queue waiting time

Average Queue Waiting Time (seconds)		
Directions/	**Base Model**	**Strategy 3 Model**
Going Up	35.25	33.30
Going Down	22.80	16.44
Average	**29.01**	**24.87**

Table 5. Distance travelled by lift cars in one hour

Distance Travelled (metres)		
Cars	**Base Model**	**Strategy 3 Model**
Car 1	792	803
Car 2	789	815
Car 3	609	844
Average	**730**	**820**

Table 6. Car loaded time as a percentage

Car Loaded Time (%)		
Cars	**Base Model**	**Strategy 3 Model**
Car 1	42.8	43.4
Car 2	42.7	44.1
Car 3	32.9	45.6
Average	**39.5**	**44.4**

From results shown in tables 4,5, and 6, it is evident that the average queue waiting time has been reduced by just over 4 seconds. This reduction in the queue waiting time is of significance as it represents nearly a 15% reduction. It is also noted that a larger reduction is possible for those passengers that are waiting to travel in a downward direction.

Table 5 shows that the car travelling distance has been increased for the strategy 3 model primarily due to the fact that the unloaded cars are regularly travelling to park at the ground floor. Whilst this increase is undesirable on the grounds of operational efficiency and energy utilization, this was expected.

Table 6, does show that strategy 3 model has increased the useful utilization of the cars. It is evident that the data set used to drive the simulation model will strongly reflect the behaviour of the model and subsequent results produced. However recognising the short simulation runs and limited iterations it is probably inappropriate to form trends without good confidence levels. Further work will address these shortcomings.

6. DISCUSSION AND CONCLUSIONS

The primary goal of this project was to simulate and build a simulation model of a real lift system in order to reduce the average queue waiting time of passenger. A real life lift system has been chosen with congestion possibilities especially when visitors open days are present. In the process of building the model, many problems arose. However previous models existed within the reseach group [10,11] that were used as reference models.

A variety of assumptions were taken as is expected meaning that the simulation model/s were different in a subtle way from the real system is. For example passengers entering the lift car is limited to only one at a time whilst in reality that may not be the case.

A simple elevator control strategy has been developed and simulated using Winess software with reasonable success. Various variants of the simple base strategy were devised, developed and simulated producing interesting results. However it became evident the data set obtained that drives the model effects the simulation results in a very serious way.

The scenario presented was the influx of 80 visitors enteringing the model in the one hour period of study. Two different strategies were devised focusing on reducing the queue waiting time and car travelling distance. Subsequently strategy 3 was developed that represented a hybrid of the earlier two strategies. Strategy 3 was the focus of the experimentation and compared with the orginal base model. Based on the results from the comparison strategy 3 is considered to operate much more efficiently as it has reduced the average queue waiting time expereineced by passengers by nearly 15%..

The performance of any elevator dispatching system operating in high volume buildings will be increasingly important to building management as passengers come to expect higher service levels in the facilities being provided by modern elevators, having little regard for the complexity of the tasks involved in getting the decision making to be optimal. There is room for improvement and potential to expand the list of strategies is the subject of further work

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