International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 4 No. 1 Sep. 2013, pp. 20-27

http://www.issr-journals.org/ijias/

Modelling a Multi-car Elevator System using Witness

O. Omar[1], M. Latif[1], and M. Awais[2]

[1]School of Engineering,
Manchester Metropolitan University (MMU),
Manchester, United Kingdom

[2]Department of Computer Science,
Lahore University of Management Science (LUMS),
Lahore, Pakistan

ABSTRACT: Elevators are considered a necessity in buildings with multiple floors. In tall buildings there is a need for efficient control of the elevator system in order to obtain satisfactory service levels. To achieve an efficient elevator control strategy a variety of diverse and sometimes conflicting constraints has to be resolved. To investigate the effectiveness of a vertical transportation system, we have developed a simulation model to analyze the call strategy of a multi-car elevator system. In this paper the main steps in the methodology for modelling elevator performance and passenger traffic in a public building are explained. Elevator dynamics and control, call allocation and passenger traffic modelling are described resulting in a Witness model. Witness simulation software has been used as a test-bed for model building, simulation and experimentation. Three different strategies were devised and experimented on the model and the results were compared to find the best average waiting time. Results indicate that the average waiting time of passengers was slightly improved when using the shortest distance strategy. In addition to passenger waiting time it has been realised that elevator performance depends on the passenger traffic patterns and, during heavy traffic, service level is greatly affected by the call allocation algorithm. The research concludes with the need to carefully select the data set as the basis for simulation comparisons.

KEYWORDS: Multi-Car Elevator, Discrete Event Simulation, Witness. Passenger lifts, Elevator dispatcher.

1 INTRODUCTION

Quality of service is demanded everywhere in today's world requiring an efficient and well organised system. As the construction of tall buildings, flats, hospitals and offices are a priority in any modern city it is therefore important to have an efficient elevator system to cope with peak times [1]. Buildings often experience elevator congestion as a result of their heavy traffic, complex user types [2]. Long wait times for passengers at floor call-points are an inconvenience especially in tall public buildings [3].Ways to improve elevator efficiency in tall buildings has become a significant problem [4].

During peak time the wait for an elevator increases causing frustration and delay which also increases the queues in the hall calls [5]. An elevator dispatching system that considers peak time is essential to prevent long queues in hall calls and most importantly reduce the average waiting time [6]. Performing real life experiments is one approach that can be taken to test the system although it will cause huge disturbance, cost and time to apply different strategies often not very practical. However computational simulation method can be applied to mimic real life behaviour of the system taking into account of passenger's random arrival rate, loading and unloading times, number of cars and the total capacity of the car can all be obtained without incurring the risk of a disturbance [7].

Corresponding Author: M. Latif (M.Latif@mmu.ac.uk)

Computational simulation model are used in various different industries mainly to help to study behaviour of a real life system and be able to experiment with system to alter the results [8]. The benefits of using simulation model are to reduce operating cost, reduce lead time, reduce risk and improve customer services. The only disadvantage using simulation is that it is not 100% accurate. Often simulations are used in flight simulators, business games due to their distinct advantages.

In this project the aim was to explore and compare different call strategies to reduce the average passenger waiting time at the North Elevators in the MMU business school building. The North Elevator comprises of 4 cars operating on 7 floors plus the ground floor with a capacity of 17 persons in each car.

On a normal working day the building experiences three peaks of elevator traffic. These are morning up peak, lunch period and evening down peak. Morning up peak is when the students and staff are coming into classes and offices from around 8:00am – 9:30am. Lunch time peak between 12:00pm – 2:00pm and evening peak between 3:00pm – 7:00pm where everyone is making the way home and uses the elevators to exit the building. Based on the data collected the lunch time traffic was the busiest time of the day where the elevators were used often in two way traffic.

WITNESS simulation software [9] was selected as a suitable tool to perform the model building, simulation and experimentation of the system under investigation primarily because of its ease of use and availability.

2 DATA COLLECTION

To guarantee the elevator simulation model is built as accurate as possible to a real life system, it is important to run an in-depth research and gather accurate data. The building of the model will be based on the research and the data collected.

There were 3 types of data collected; firstly data was collected through observation. Outside every car on each floor was a volunteer who stood and counted how many people who entered the car and how many passengers exited. These observations were made for thirty minutes during peak time. Secondly data and travelling preferences was based on the results of a questionnaire completed by participating passengers and thirdly a physical layout and specification of the elevator system was obtained from building services.

Before manually collecting the data it was important to know when peak time occurs during the day. By observation lunch time was the busiest time of the day. One method used to collect data was to observe the volume of passengers that used the elevators. This observation was made on each floor of the building and were conducted 15 minutes before the hour and 15 minutes after the hour for period of 30 minutes. Analysing the data obtained showed that the passengers were arriving at the ground floor call point with an inter-arrival time of 2 seconds (exponentially distributed).

A self-complete questionnaire was obtained from 50 passengers covering quantitative data. This method of gaining data was specifically chosen, as it was the most efficient way of gaining valuable information. The results were then observed, analysed and used to input the statistical data.

3 ELEVATOR DETAILS

Before building the simulation model, it was necessary to determine how and why the elevator operates in its present manner. According to the online research, elevators behave differently depending on the type of building they are built in. So for instance, elevators in a hotel will behave differently to elevators in an office building. Office building elevator will only operate for set period of the day whereas hotel elevators run 24 hours a day. The university building acts like an office building as they operate in the same manner throughout the day.

Elevator systems have strategic ways of operating during peak times and have different methods of detecting these peak times. Since the peak time occur randomly. The current elevator does not estimate peak time hours, as it has another way of detecting peak time. The North Elevator in the business school utilises weight sensors to detect peak time. These sensors are placed in the floor of each car to measure the total weight. If that weight exceeds a curtain value than it will alert other cars that it is busy on a specific floor.

Elevator information:

- Elevator in group: 4 cars
- Rated car load: 17 persons
- Rated speed: 1.75 m/s
- Door opening type: Centre
- Door width: 1100mm

- Door closing time: 2.7 s
- Door opening time: 1.2 s
- Transfer time: 2.0 s

4 MODELLING THE SYSTEM

To successfully build a dynamic model representing an elevator, some essential simulation elements need to be setup. Witness is equipped for this task as it uses a variety of elements to represent real world elements. These elements are described next.

Passengers (entity): This is the first step of the process when the passengers enter the building and they will either call for the car or join a queue if the car is already been called for. The passengers are pushed into an activity and grouped to be transported by the car.

Exit (Activity): Exit activity represents the passengers leaving the building and this occurs once the passengers are back down to the ground floor.

Qin & Qout (Queue): Qin simply shows the number of queues in each floor waiting for the elevator car to arrive however one entity (passenger) does not represent one passenger as they have been grouped. Qout out is not really a queue it just shows that the passengers have exited from the elevator car on to that floor.

Lift Car (Vehicle): There are four cars for the elevator system with each operating on its own track. The car spends at least 5.9 seconds on each floor and this is because it takes 1.2 seconds to open the door, 2 seconds for transfer time and 2.7 to close the door. Sometime the transfer time might increase based on the number of passengers entering and leaving the car. The car takes 5 seconds to travel between each floor.

Lift track (track): Lift track consists of eight floors and 35 tracks. In every 5th track is 1 floor so up to track 5 is first floor and track 10 is second floor. Each track takes one second for the cart to travel on which means in every 5 track it takes 5 seconds. The total height distance of the real life track is 26.6 metres from ground floor to the 7^{th} floor and the height between each floor is 3.8 metres.

Floor & Stairs (Conveyor): The floor conveyor represents how long the passengers spend on a floor usually 55 minutes since they are in classes most of the time. The stairs conveyor allows passengers to use the stairs instead of the elevator on the way down. Actual decisions were based on observational data that was implemented as a varying percentage.

4.1 MODEL BUILDING

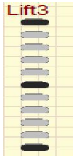
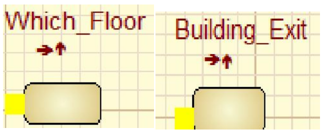
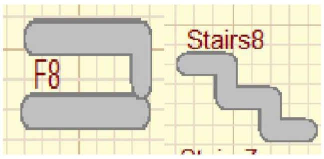
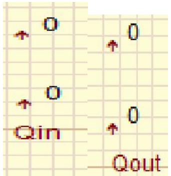
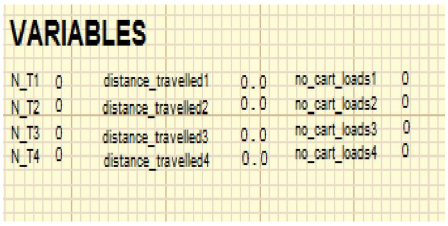
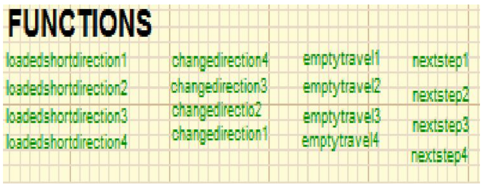
The operational sequence was passengers arrived at an elevator call point on any floor, waited for the car, entered the car and either travelled to an upper floor or travelled to the ground floor. At this stage it was deemed appropriate to only consider passengers entering or leaving the building. Inter-floor movements were not considered.

Based on observations it was realised that not all the passengers on the upper floors used the elevators to go back down therefore stairs were added to the model. Passenger from third, second, and first floor mostly used the stairs to get down whilst passengers on the fourth and above floors mostly used the elevator to get to the ground.

Once all cars were operating successfully conveyor elements were used to represent the time spent on the floor and also to represent stairs.

Table 1 shows the mapping of the Witness modelling elements into the developed multi-car elevator system.

Table 1. Mapping of witness elements

WITNESS Graphic Element	WITNESS Feature	Description
	Vehicle	Lift car
	Track	Lift track
	Activity	Which floor: dispatcher Building Exit
	Conveyor	Time on floor Stairs
	Queue	Queue waiting for lift and exiting the lift
	Variables	Displays information in number e.g. distance_travelled1: 200
	Function	Applying formulas

4.2 Base Model

Building the base model was complex because of having to use four cars to work as a group and in many occasions they interfered with each other sometimes causing confusion. An overlying theme of the model building was to minimize the model size and usage of elements. The final model built is shown in figure 1.

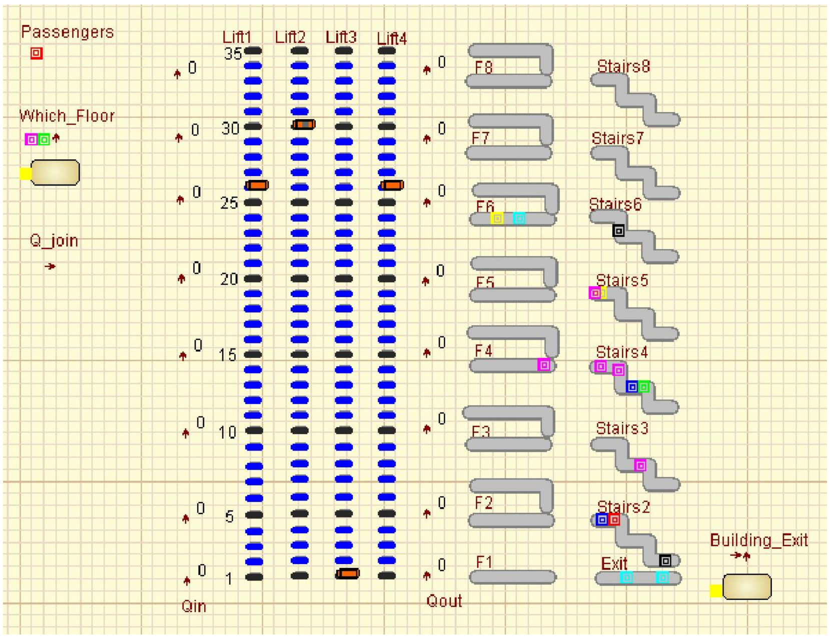


Fig. 1. Base model of elevator

4.3 Model Validation and Verification

Verification and validation were separately performed on base model essentially to confirm the accuracy of the model. Verification was applied during model building to test the behaviour of each element as if it would be in the real world. Validation was performed by exploring the consistency and credibility of the model results.

5 Simulation Scenarios

The base model was simulated for one hour of peak time operations and the results obtained are shown in table 2. Two new strategies were devised and applied which were zone strategy and track position.

5.1 Base model

The base model represents the "as is" elevator system. The system detects peak time by using weighing sensors. This method uses a sensor which is installed in the surface of the vehicle of the elevator which calculates the total mass inside the lift and if it exceeds a certain value than it will know its peak time. Once a car experiences peak activity then it will communicate with the other three cars requesting that busy floor to become the loading floor for the other 3 cars.

5.2 Zone Strategy

This type of strategy is mainly used in tall office buildings because usually the problem occurs when the car is going up it will stop at each floor and pick up passengers on the way. By the time the car reaches higher floors it will be full resulting in longer wait times for higher floor passengers. The zone strategy essentially splits the demand load and assigns two cars to operate between ground and floor 3. Whilst the remaining two cars will operate between floors 4 to 7 and the ground floor.

5.3 Track Position

This strategy uses a shortest distance to call point strategy which is simple and effective. The closest elevator car will respond to the call based if they are free which is normally how an elevator will operate during non-peak time.

6 SIMULATION RESULTS AND DISCUSSIONS

The aim was to reduce the average waiting time. The three models were run for one hour using identical passenger arrivals and the results were gathered and are as shown in table 2 for comparison.

Table 2. Average waiting time at call point

	Average Waiting Time (seconds)		
Floors	**Base model**	**Zone model**	**Track position**
Qin(1)	7.63	9.31	3.81
Qin(2)	5.71	9.53	13.71
Qin(3)	7.54	5.41	3.81
Qin(4)	14.82	12.91	9.73
Qin(5)	13.41	51.31	8.72
Qin(6)	11.42	15.93	14.42
Qin(7)	7.83	82.80	14.67
Qin(8)	23.54	261.42	15.81
Total Average (sec)	**11.49**	**56.08**	**10.59**

Table 2 shows the average waiting time on each floor for all 3 strategies. The base model has a consistently distributed waiting time for all the floors and not a big difference between each floor apart from the 7th floor. The zone strategy highlights issues with excessively large queue waiting times especially on the 7th floor. Track position strategy waiting time shows really good times in the lower floors but also shows passengers in upper level floors will wait longer than passengers at the lower levels.

From table 2 track position strategy has the best average waiting time of 10.59 seconds and 11.49 seconds for the base model. However the zone strategy has an unacceptable average waiting time of 56.08 seconds. From the average waiting times in table 2, it is evident that the zone strategy appears not to be effective for the higher floors due to longer travel time incurred to service the higher floors.

Clearly the track position strategy would be advantageous for this data set

Table 3. Usage of elevator cars

Elevator Car Free (%)			
Name	Base Model	Zone strategy	Track position
Car 1	32.42	45.75	50.6
Car 2	27.03	38.48	46.19
Car 3	22.05	35.54	38.7
Car 4	20.44	38.09	34.95
Average %	**25.49**	**39.47**	**42.62**

Table 3 indicates the usage percentage of each elevator car for the three scenarios over the course of the one hour's simulation. It can be seen in table 3 that base model appears to be most productive and the track position strategy as least productive. From these results it can be deduced that the track position strategy would have more spare capacity than the other two scenarios producing a better option.

Table 4. Distances Travelled

Distance Travelled (m)			
Name	Base Model	Zone strategy	Track position
Car 1	3765	1729	2572
Car 2	2745	1322	2204
Car 3	2454	3563	2211
Car 4	1947	2521	2777
Average (m)	**2728**	**2284**	**2441**

From table 4 it can be seen that in the base model car 1 has covered the most distance which suggest that car 1 has the most work load and car 4 has the least work load. This means when the call is made it will always check if car 1 is free first then car 2, car 3 and then car 4 regardless which one was free first. The zone strategy shows that car 1 and 3 have covered the longer distance and same method is applied as base model but this time from ground floor to the 4th floor the dispatcher will always check for car 1 and then car 2. From 5th floor to 7th it looks at car 3 first and then car 4. Track position has a more evenly distributed work load as the distances covered are close to each other. Overall the zone strategy produces the lowest average distance travelled

Overall the track position strategy has produced the least (average) queue waiting time with minimum effort (maximum % free). Since the main aim of the project was to explore a reduction in queue waiting time then the track position strategy appears to be advantageous over the other two strategies.

7 CONCLUSION

The use of a visually interactive simulator has been shown to effectively and dynamically simulate the behaviour of a multi-car elevator system. The technique of representing people as a series of entities enables the use of high quality animation in the simulation which improves the display at the human/computer interface.

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

The main aim of this project was to explore elevator call strategies that would ultimately reduce the average waiting time experienced by passengers at floor call points. The investigation gathered observation data and also using questionnaires/interview. A base model representing the multi-car elevator system was built and the system simulated to represent operations during a peak hour of demand. The model was built satisfactorily; it was validated and verified to insure that it behaved realistically. The result obtained from the base model was verified with reasonable accuracy with observational data demonstrating confidence of the results.

Two varying strategies, Zone and Track position, were devised and implemented to test and compare against the original strategy. The most efficient strategy experimented with was the track position. This produced the least average queue waiting time which was the main aim of the project. However it is realised that these results are very dependent on the data set used and minor changes to the model can have a serious effect on the results. Clearly there are many avenues for investigation and potential improvements to the model. These will be explored in future work.

REFERENCES

[1] Cortes, P., Onieva, Luis., Munuzuri J., and Guadix, J. "A viral system algorithm to optimize the car dispatching in elevator group control systems of tall buildings", *Computers & Industrial Engineering*, vol 64, pp 403-411,2012

[2] Nagatani, T., "Complex motion in nonlinear-map model of elevators in energy-saving traffic", *Physics Letters A*, 375 (2011), 2047-2050

[3] Tebbenhof, A., Dekker, R., "Econometrics in the elevator". *Medium for Econometric Applications*, 9(3), 26-30, 2000

[4] CIBSE Guide D: Transportations systems in Buildings, Third Edition, CIBSE Publications, London, 2005.

[5] Mulvaney, D., White, J., Hamdi, M., Elevator dispatching using heuristic search, *Intelligent Automation and Soft Computing*, 16(1), 77-182, 2010

[6] Peter, R., Mehta, P., Haddon, J., “Lift passenger traffic patterns: applications, current knowledge and measurement”, *Elevator World*, 48(9), 87-94, 2000

[7] Horejsi, J., Horejsi, P., Latif, M., “Strategies for an Elevator Dispatcher System”, *Modern Machinery Science Journal*, July 2011, 234-238

[8] Bolat, B., Cortes, P., “Genetic and tabu search approaches for optimising the hall call – Car allocation problem in elevator group systems”, *Applied Soft Computing*, 11,1792-1800,2011

[9] Witness, The Lanner Group plc, [Online] Available: http://www.lanner.com, (June 3, 2013)