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Designing Elevator Installations Using Modern Estimates of Passenger Demand

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Key Words: traffic analysis, simulation, dispatching, traffic patterns

ABSTRACT

Research shows that the traditional assumptions of elevator passenger demand in office buildings may no longer be applicable to modern buildings. The differences between traditional and modern patterns of passenger demand in office buildings are discussed. The significance of these differences on elevator system design including the quantity and size of elevators as well as the environmental and financial impacts are explored.

1. INTRODUCTION

The quantity of passengers to be transported by an elevator system is a primary consideration in elevator system design.

Our research indicates that passenger demand in modern office buildings is significantly different to the assumptions formed many decades ago, but still applied to most modern designs.

The number and type of elevators required to provide a proper and efficient elevator service may need to be revised based on these findings. These changes in elevator system design have economic and environmental consequences that are favourable.

2. HISTORICAL REPRESENTATIONS OF PASSENGER DEMAND

A plot of passenger demand depicts the level of passenger traffic in a group of elevators over a period of time. Figure 1 shows estimated passenger demand for an office building over the working day with a population of 1000 people. This has been generated by applying the example of office passenger demand presented by Strakosch in *The Vertical Transportation Handbook* [1]. In this representation of passenger demand, passengers travelling up the building are shown in the top section of the graph, with passengers travelling down in the lower section.

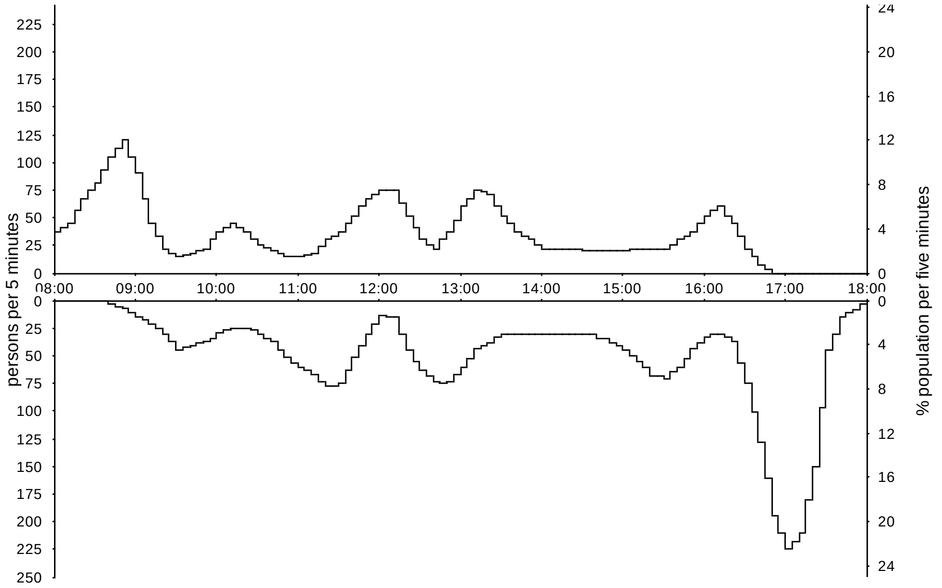

Figure 1 Passenger demand based on presentation by Strakosch

A similar pattern of office demand developed by Barney is presented in CIBSE Guide D [2] and Elevator Traffic Analysis Design and Control [3].

The basis of these presentations is believed to be data acquired at a single building in the USA in the early 1960's. Many, including the authors of this paper, believe this building and its pattern of traffic demand to be typical of major city office buildings during this era.

It was generally believed that the most demanding traffic type was the morning up peak. This belief was reinforced by research conducted by Barney who showed that elevators have between 20% and 60% more capacity during non up-peak conditions [4].

Anyone who has visited major cities over the last 40 years will attest to the fact that many things have changed. One may reasonably question how applicable a passenger demand pattern that existed over forty years ago is to a present day building.

3. MODERN BUILDINGS

3.1 Previous work

How people use elevators and the traffic patterns that their use generates has changed since 1923, when Basset Jones published formulae for the expected number of stops a car will make during a round trip [4]. Summarising the results of a series of peak time traffic surveys carried out between 1993 and 1997 Peters concluded, "Morning traffic peaks are less marked in buildings than they were when traditional up peak design criteria were formulated. In work-related buildings occupied during the day, the busiest period appears to be over the lunch period" [5]. In 2002, Bruce Powell, discussing modern office buildings states "two-way traffic at noontime is often a more severe test of elevators than up-peak" [6].

In 2000 Siikonen presented a traffic pattern that represents traffic measured in a modern installation [7]. Siikonen presented data as a stacked area graph, but for consistency with

Figures 1, the same data is presented in Figure 2 showing incoming and outgoing traffic separately.

This pattern is quite different from the traffic pattern presented by Strakosch. Siikonen shows a lunch up peak that is the same size as the morning up peak. Additionally, the down peak at lunch is more intense than the evening down peak. The Strakosch lunch period shows a down peak followed by an up peak, which is followed by a smaller down and up peak. These double peaks do not occur in the Siikonen pattern. These observations raise a question, are the differences in the patterns due to the unique nature of the building studied by Siikonen or have traffic patterns changed over the years?

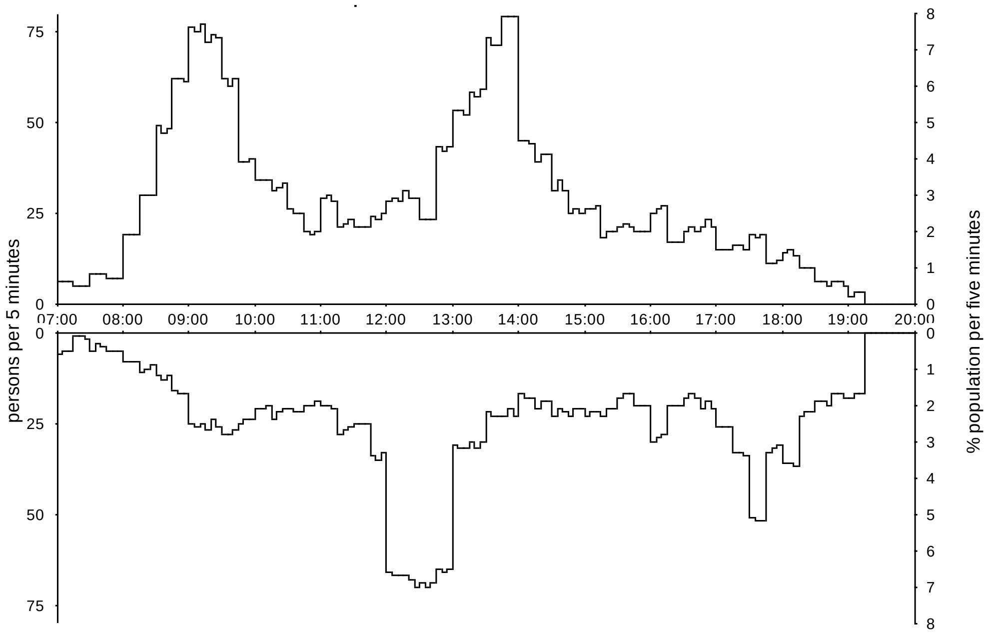

Figure 2 Passenger demand based on presentation by Siikonen

The traffic pattern presented by Siikonen could be building specific, or it could represent a basic shift in traffic patterns.

In order to understand better modern elevator traffic, data was collected at a number of office buildings in different parts of the world including Europe, North America and the United Arab Emirates.

In most cases data was collected by manual count. However, in one building, data from three groups of elevators in a corporate headquarters building was gathered electronically.

3.2 Manual counts

Figure 3 shows the results of elevator traffic surveys for seven separate groups of elevators [8]. The surveys were undertaken applying a methodology defined by Peters and Evans [9]. The passenger demand is normalised against observed population to allow results to be compared between buildings. The observed population is the maximum occupancy of the building on the day of the survey, and is often significantly lower than the population reported by building management.

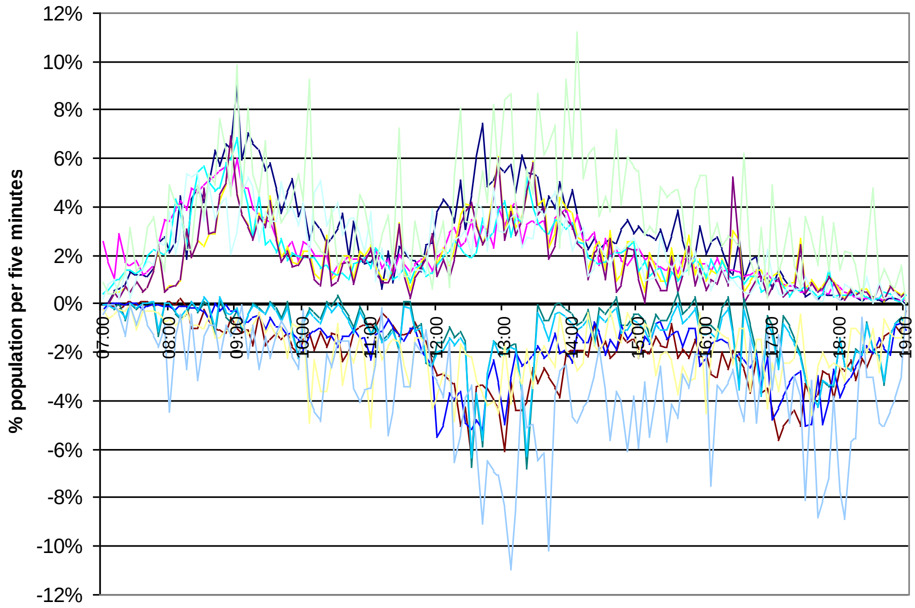

Figure 3 Passenger demand based on manual traffic surveys

On average, the mix of traffic during the morning up peak was found to be approximately 85% incoming, 10% outgoing and 5% interfloor. During the busiest part of lunch the mix was found to be 45% incoming, 45% outgoing and 10% interfloor.

3.3 Automatic counts

It is difficult to count automatically the number of passengers using elevators with conventional control systems which have up and down call buttons on the landings [2], as they only count calls, and there is often more than one person behind a call. With a destination control system each passenger registers which floor they want to travel to on the landing. A destination control system based on the ETD algorithm [10] was used to log the operation of the elevators including every destination call. The logged data was replayed in the Elevate simulation program mapping destination calls to people, resulting in an estimate of passenger demand [11].

Figures 4 records the estimated passenger demand of one of the three elevator groups in a corporate headquarters building in the USA as presented in [11]. The measurements for five consecutive work days are superimposed in this figure. Each group has a recognisable passenger demand pattern or “signature”.

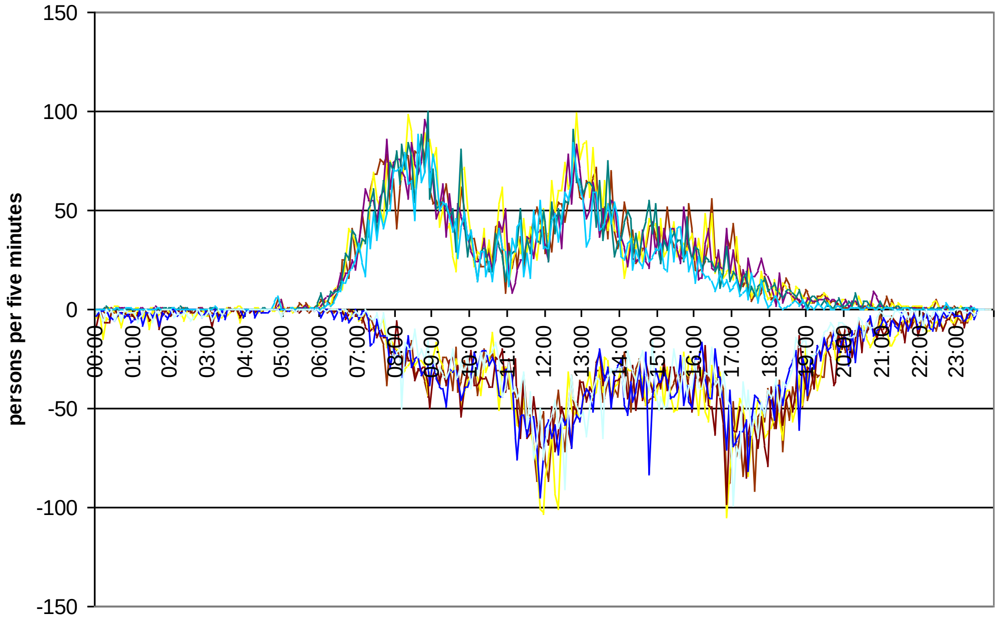

Figure 4   Low rise passenger demand signature

4. DISCUSSION OF TRAFFIC SURVEY RESULTS

In most modern office buildings, there is a greater demand at lunchtime than in the morning. However, both morning and lunch periods need to be considered as part of the design process. In the morning, the elevators are more crowded as people are mostly travelling in one direction and are in the car together. At lunch time, incoming and outgoing traffic are not in the car together, which makes the cars less crowded (provided that the building is not under-elevatored). However, at lunchtime, the cars stop more often, leading to longer waiting times.

None of the groups surveyed have the sharp down peak that is seen in the Strakosch pattern. In modern office buildings with professional workers, a significant portion of office workers work more flexible hours and later than in previous years.

In one building the total peak demand exceeded 18%. This is characteristic of buildings with low population. In this survey, the population served by the elevators was approximately 200 people. Thus 1% of the population equates to 2 people. With a larger sample size, for example, if the survey was repeated on multiple days, one could expect the average peak to be lower. It is not necessary to design to these high peaks as they do not occur in larger buildings, and in smaller buildings they represent a small number of people and queues will be cleared in a short time because the high demand will not be sustained.

Figure 5 shows the range of total passenger demand measured by manual survey in major offices with an observed population in excess of 1000 people. Total demand includes incoming, outgoing and interfloor traffic.

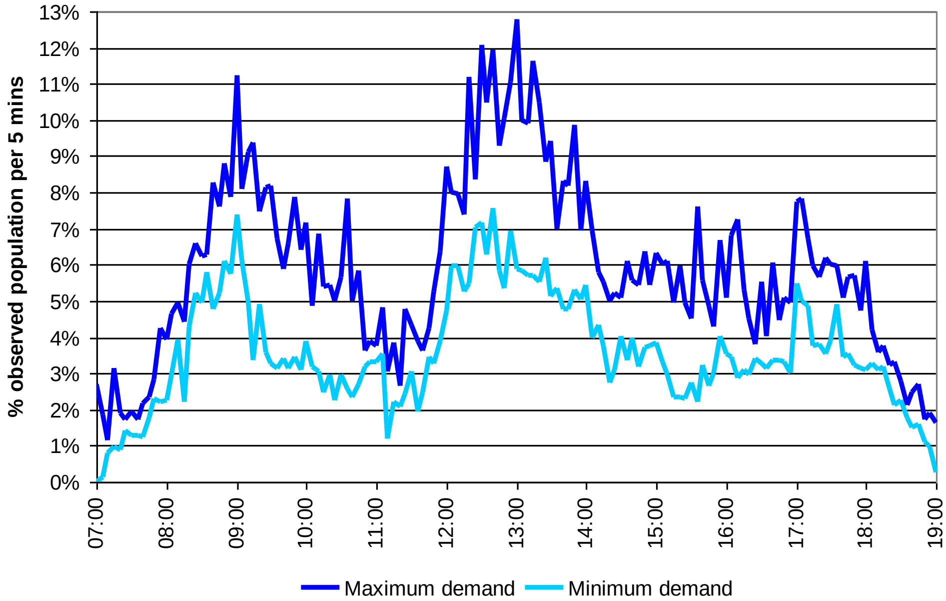

Figure 5   Passenger demand range for major office buildings

5. IMPROVEMENTS IN ELEVATOR PERFORMANCE

5.1 General

Elevator systems have evolved over the past 40 years. At the premium end of the market there are microprocessor based destination control systems, high performance closed loop door operators and highly responsive permanent magnet AC motors and drives. Some suppliers offer further enhancements, for example V-max [12] where the top speed of the elevator can be greater than the traditional “Contract Speed”.

A step profile can be used to investigate the relative performance of different elevator systems at varying traffic intensities. The simulation starts with a low passenger demand, which is then increased in steps. In the following simulation results by Smith [13] the steps are very small (0.1% of the population served by the elevators) to enhance the definition of the results. Results are presented as a Quality Quantity Map (QQM), which highlights the increasing average waiting time and average time to destination as the passenger demand increases.

5.2 Up peak Analysis

Figure 6 is a QQM for a sample traditional six car elevator system with a group collective controller. The door system and kinematics are similar to those which an average performing system can provide. The traffic mix used for this analysis was 85% incoming, 10% outgoing, and 5% interfloor, based on the surveys of up peak traffic.

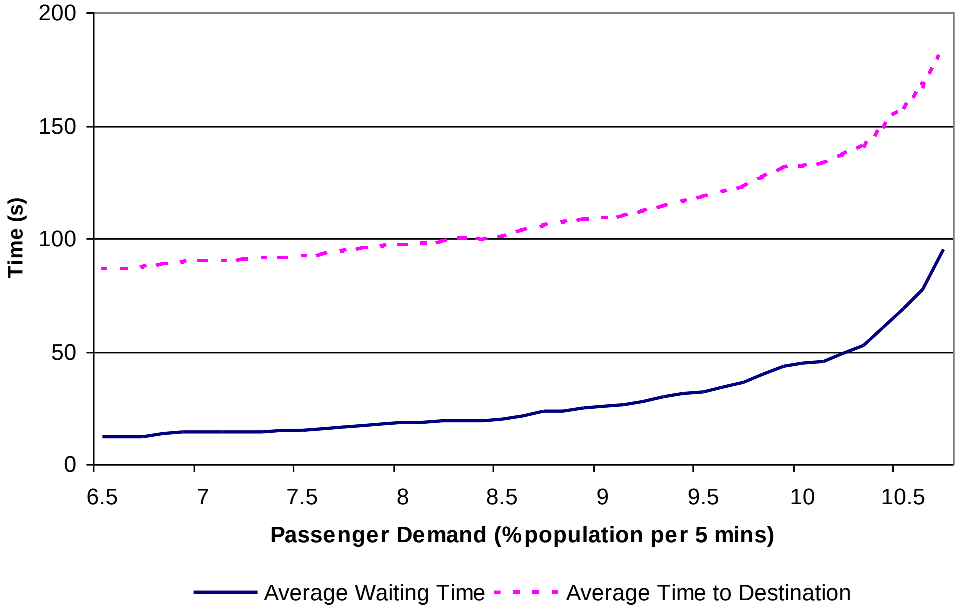

Figure 6 QQM for traditional up peak installation with six cars

Figure 7 is a QQM of the identical building and traffic mix, but in this instance the elevators are fitted with high performance doors, ThyssenKrupp Elevator's destination dispatch system and V-max.

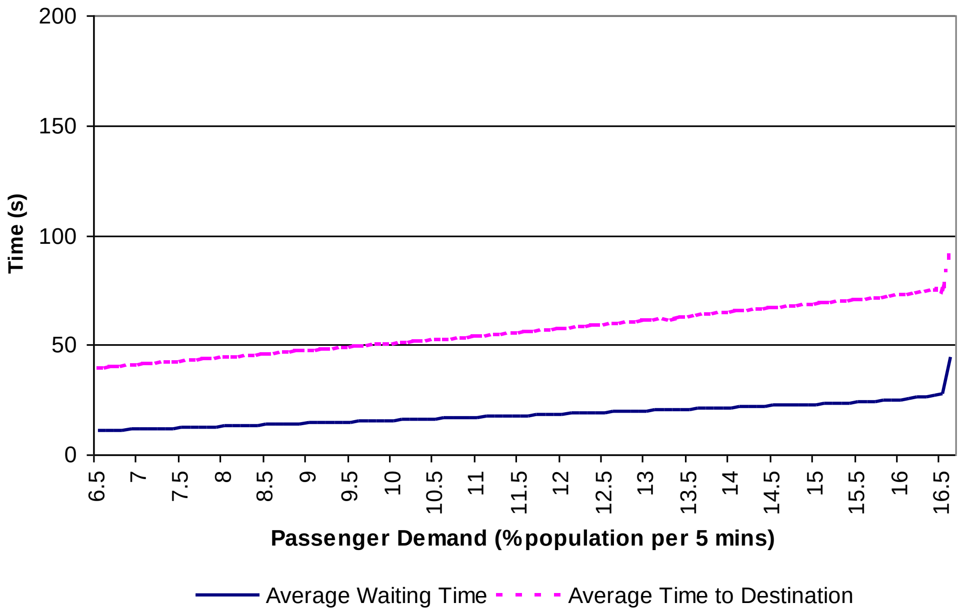

Figure 7 QQM for enhanced up peak installation with six cars

What is the correct number of elevators for this building?

Using traditional traffic analysis based on Up Peak Round Trip Time, the 18 story office building shown in the QQM's is fitted with six 1350kg elevators operating at 2.5m/s would have an interval of 30.9 seconds and a 5 minute handling capacity of 12.7% of building capacity. The quality and quantities of service are very close to the normally recommended values. One might conclude that this system would be adequate for this building.

However, with modern traffic patterns and employing advanced technology elevators is the recommendation of six elevators too many?

In order to evaluate this possibility a Comparative QQM was developed to compare five high performance elevators with six traditional elevators during an up peak with a traffic mix of 85% incoming, 10% outgoing, and 5% interfloor.

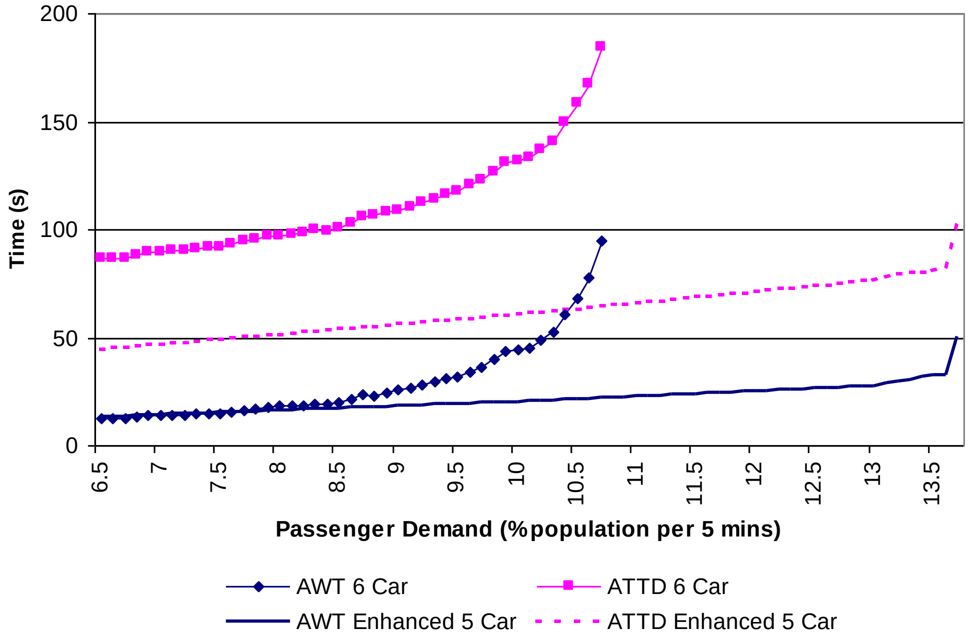

Figure 8   Up peak CQQM for traditional six cars versus enhanced five cars

In Figure 8 it can be seen that the five car enhanced system outperforms the six car traditional system at all traffic levels and saturates at a much higher traffic level. This five car system can be expected to provide good service when the traffic levels our research indicates can be expected.

5.3 Lunch peak

Lunchtime traffic is believed to be more demanding on an elevator system than morning up peak traffic. Additionally, it is widely accepted that destination control provides less benefit when compared to traditional dispatching systems at lunch time than in the morning.

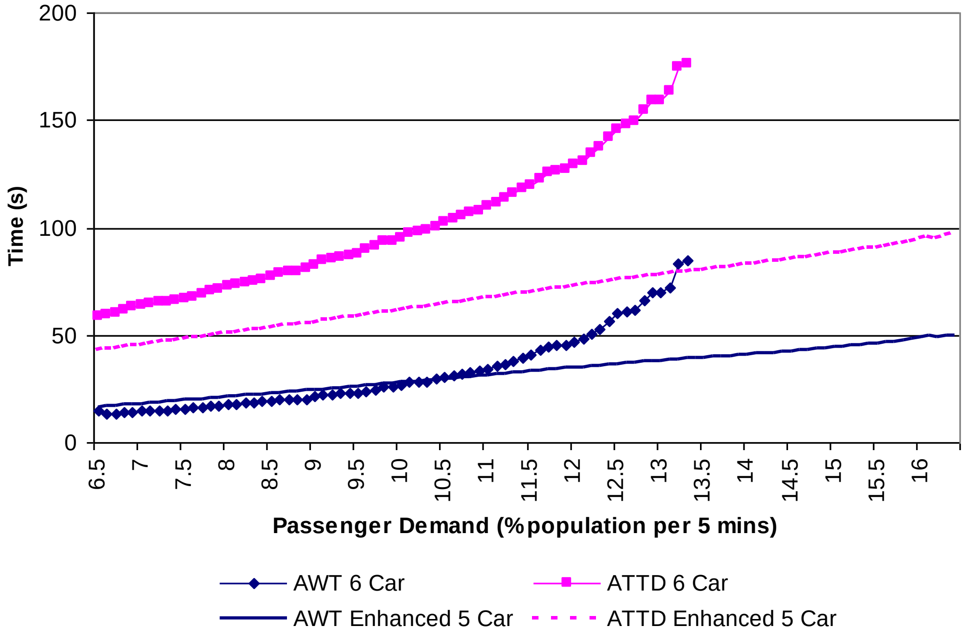

Figure 9 Lunch peak CQQM for traditional six cars versus enhanced five cars

In Figure 9 it can be seen that the enhanced five car system saturates at a much higher level than the six car traditional system and at every traffic level has a lower time to destination. However, the traditional six car system has slightly lower waiting times when the traffic level is below 10.4%.

For this example it can also be shown that enhanced system with one car out of service provides better service than the traditional system with one car out of service.

6. ECONOMIC CONSIDERATIONS

Depending on where the elevator is manufactured, the cost of an enhanced, high performing system will represent an increased cost of between 5% and 10% per unit [14].

For simplicity the cost of each traditional elevator is assumed to be €250 000 and the cost of each high performance elevator to be €275 000. So for the example in section 5, the traditional six car system would cost €1 500 000 and the high performance five car installation system €1 375 000.

The need for fewer hoistways will also produce savings. The cost of a hoistway includes the hoistway, the electrical service for the elevator, the shaft lighting, the pit and associated excavation, and in some cases a machine room. Lobby area may also be reduced.

For example, consider an 18 floor office building where saving one elevator produces a total reduction in hoistway and lobby area of 10 m² per floor. Over 18 floors, this yields a saving of 180 m². If this space was rented for €250/m²/annum, then annual rental increase would be €45 000.

Strakosch wrote in the first (1967) edition of The Vertical Transportation Handbook [1] that the monthly price of full maintenance on traction elevators was equal to 0.33% of the purchase price. This percentage is still typical today. Although high performance elevators cost more per unit to maintain, the overall purchase price is lower than traditional systems and thus the overall maintenance price should also be lower. If the installation is relying on high performance to deliver an acceptable service, the highest grade of maintenance contract will always be required; the client should always be made aware that this is an assumption of the design and have an appropriate monitoring system so that passenger demand and elevator performance can be monitored.

7. ENVIRONMENTAL CONSIDERATIONS

Installing fewer higher performing elevators has an impact on the energy consumption of the installation.

Peters [15] has demonstrated using Life Cycle Analysis that the dominating environmental burdens of an elevator are the non-renewable resources depleted, the waste created and the emissions generated through the production of electricity for operation of the elevators while in use. Use of renewable resources in manufacture, recycling and re-use, efficient transport, disposal/spillage of hydraulic oil, etc. are all important, but secondary issues.

Elevator simulation can be applied in conjunction with an energy model to determine the difference in energy consumption between the traditional and enhanced system [16]. Smith ran a full day's simulation, applying the same high efficiency regenerative drives for both options [13]. This demonstrated a 3% energy saving of the enhanced system over the traditional system. This value will be drive dependant, and in this case is a relatively small saving is because of low losses in the drive. Furthermore, the systems are transporting the same number of passengers, so the same overall work is done, although with less total trips. The small reduction in energy consumption can be attributed mostly to the energy consumed by the individual control system when it is on standby. This steady state load is less with fewer elevators.

The energy simulations did not include cabin lighting and ventilation which vary from installation to installation based upon architectural requirements. Fewer elevators will also equate to lower lighting and ventilation loads, even if switched off when not in use.

Many electric power providers charge a fee based upon the maximum load connected to the system. Reducing the number of elevators reduces the total load connected to the system therefore there may be some small additional reduction in energy costs.

6. DISCUSSION AND CONCLUSIONS

Analysis based on realistic traffic estimates is the best way to predict the quality of service provided to passengers.

New design templates which take into account passenger demand research and recognize the benefits of enhanced technologies will be published together with guidance on their application in the latest revision of CIBSE Guide D [2] to be published in 2010. The new templates are also included in Elevate Version 8 [17].

All assumptions about performance should be verified with the elevator supplier. It will not be unusual, and is possible for different suppliers to claim higher performance for equipment with nominally the same specification. However it is common for elevators not to perform as well as has been assumed in design calculations and simulations. For this reason, in most cases elevator selection should normally be based on generic equipment, and not rely on the enhanced performance claims of one or more supplier. Before making an exception, the customer should consider:

1. Is a supplier guaranteeing enhanced performance definitely going to be awarded the contract, or could a lower cost tender be selected?
2. Has enhanced performance been provided consistently by the suppliers under consideration for installations in the geographical region of the new installation?
3. Are the suppliers under consideration prepared to have this enhanced performance verified independently so that the customer does not have to rely on assertions made as part of competitive sales bids?
4. After specifying an enhanced system, is it possible that it may be value engineered by the customer into a lower performing system?
5. Will the system be maintained in a manner that maintains the design performance and will it be fully monitored to confirm this to the customer?

The example in this paper may lead one to conclude that in some cases too many elevators are being provided due to the changes in traffic flow, usage and elevator technology. However in some instances promised elevator performance does not match simulated performance. The designer should proceed with caution.

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BIOGRAPHICAL DETAILS

Richard Peters is a Director of Peters Research Ltd. Dr. Peters has a degree in Electrical Engineering, and Doctorate for research in Vertical Transportation. He has been developing traffic analysis, simulation and dispatching software since 1986. He is married with two daughters, living in High Wycombe, England.

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