Beyond the Up Peak

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ABSTRACT

The up peak round trip time calculation (UPRTTC) was designed to be performed by hand. Implemented in software, the UPRTTC can now be performed quickly and efficiently. However, the UPRTTC is incapable of assessing the performance of all but up peak traffic in buildings with the main entrance on the lowest floor. More flexible analysis techniques are possible with calculations designed specifically to be implemented on computers. In this paper the authors compare two established software based techniques - General Analysis and Simulation - with the UPRTTC, discuss their relative merits, and compare the outcomes for some example buildings.

1. INTRODUCTION

The up peak round trip time calculation (UPRTTC) was designed to be performed by hand calculation. To simplify the exercise, it is assumed that all passengers arrive at the lowest floor and travel up the building. Passenger destinations are taken to be proportional to floor populations. The time taken for a single lift to complete a single "round trip" is estimated. The round trip time (RTT) is divided by the number of lifts to determine a system interval.

In *CIBSE Guide D* (Various authors 1993), Barney records that a recognized method of UPRTTC evolved by the 1970's, based on the mathematical determination of average highest reversal floor (Schroeder 1955) and calculation of average number of stops (Basset Jones 1923). Formulae given in *Elevator Traffic Analysis Design and Control* (Barney and Dos Santos 1985) for the passenger handling performance of lift systems are widely accepted.

The standard up peak calculation is a valuable tool, but is limited in its application. For example,

- the UPRTTC only considers up peak traffic; this is not always the most onerous traffic flow in buildings
- in some instances the UPRTTC is inappropriate, e.g. in shopping centres, car parks, airports, hospitals and hotels
- it is difficult to adjust the UPRTTC to analyse up peaks in buildings with basements which are occupied

Today, most designers use a computer program to perform lift traffic calculations. As it is no longer necessary for calculations to be performed manually, it has been possible to develop far more sophisticated techniques. In this paper we will discuss and compare the UPRTTC with two other methods that are widely applied in computer programs. These are the General Analysis (Peters 1990, 1992) and Simulation (Barney and Dos Santos 1985)(Peters 1998).

2. GENERAL ANALYSIS CALCULATION

The General Analysis allows RTT calculations to be performed for any peak traffic flow. This overcomes most of the limitations associated with the UPRTTC.

You can use the General Analysis for an UPRTTC by specifying up peak handling capacity and calculating interval. But, to define more complex traffic flows, we need a more comprehensive way of describing the passenger traffic. To do this, we need two variables:

μ_i the passenger arrival rate at floor i (defined for each floor at which passengers may arrive)

d_{ij} the probability of the destination floor of passengers from floor i being the jth floor (defined for all possible i and j)

Using these terms, a simple up peak traffic flow in an office block could be represented as in Figure 1. And a more complex traffic flow could be represented as in Figure 2.

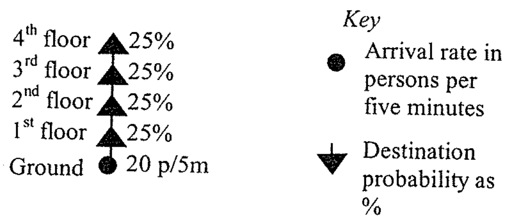

Figure 1 Simple office traffic flow

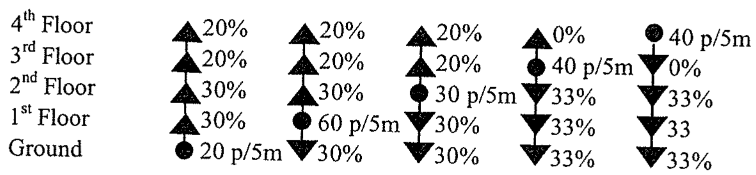

Figure 2 Complex traffic flow

Since its introduction in 1989 the General Analysis has been used extensively. The technique is too complex to perform by hand, but has been implemented in various software programs, including commercially available packages.

3. SIMULATION

With Simulation we model the whole process of passengers arriving at the landings, pressing the landing call buttons, getting into the lifts when they arrive, and then getting out at their destinations.

Simulation has a number of advantages over RTT calculations:

- RTT calculations simplify the analysis in order to be able to formulate the problem in mathematical terms. We extrapolate results from an "average" trip in the "average" round trip of a single lift. With Simulation, we model *every* lift trip thereby avoiding the need to work with average trips.

- RTT calculations give results in terms of interval. Quality of lift service is better measured in terms of passenger waiting and transit times, which are calculated by Simulation.

- Simulation is visibly closer to "real life", and therefore more intuitive. Watching a Simulation gives a far better understanding of the operation of the lift system; you can see the lifts answering the calls, and queues forming at the landings.

Like the General Analysis, Simulation can be used to analyse any peak traffic flow. As for the General Analysis, arrival rates and destination probabilities are a good way of defining traffic flows for Simulation.

Simulation can also be used to model:

- Light (non-peak) traffic
- Changing levels of traffic, for example the increasing levels of traffic as the work start time approaches in an office building
- Mixed types of traffic, for example goods and passenger traffic using the same lifts
- Lifts in the same group with different speeds and sizes
- Groups of lifts where not all the lifts serve all the floors (for example, if only two of four lifts serve the basement)

4. RELATIONSHIP BETWEEN AWT AND INTERVAL

Interval is a poorly understood term. It is the average time between lifts departing from the main terminal floor. So, if you have an interval of 25 seconds during an up peak, a lift should depart about every 25 seconds.

Interval is often confused with average waiting time (AWT). The waiting time is the actual time a passenger waits after registering a landing call (or entering the queue if a call has already been registered) until the responding lift doors begin to open. AWT is a better measure of the quality of service experienced by passengers than interval.

The theoretical average wait of a person is half the interval (Strakosch 1983). If the interval is 30 seconds, some people will arrive just before the lift departs and will not have to wait at all. Others will arrive just after the lift departs and will have to wait 30 seconds. On average, a person should have to wait 15 seconds.

In practice lifts do not operate the perfect, equally spaced service assumed by RTT calculations in the determination of interval. Strakosch goes on to suggest that with the best available operating systems, AWT should be about 55 to 60% of the interval.

Barney shows a correlation between interval and AWT in *CIBSE Guide D* (Various Authors, 1993). Barney has found that the relationship is affected by the loading of the lift, and gives guidance for estimating AWT from interval according to car load. Barney also states that in practice cars load to between 60 to 70% of the numbers permitted by the rating plate. At this car loading, Barney's estimate for AWT would be 50% to 65% of interval.

If simulation had been available when traffic calculations were devised, it is unlikely that interval would ever have been considered. But as interval is much easier to calculate than AWT, most lift performance guidelines are given in terms of interval. Now that simulation is widely available, what corresponding AWT should we design to?

Taking recommendations from both Strakosch and Barney into account, an AWT/interval ratio of 60% would be reasonable for the up peak traffic condition with fully utilised lifts. So, if we have in the past designed an office building to have a maximum up peak interval of 30 seconds, a maximum 18 seconds AWT would be a good guide to the quality of service required.

5. INTRODUCTION TO EXAMPLES

In examples 1 and 2, the calculations have been repeated for a range of lift numbers and speeds. To limit the number of options, the lift car size has been fixed at 1250 kg in the graphs of results. (The purpose of the calculations is to compare the analysis techniques rather than find the "best" solution.)

All the following examples have been calculated using *Elevate* traffic analysis and simulation software from Peters Research Ltd. The program has a range of analysis options including UPRTTC, General Analysis calculations and Simulation.

EXAMPLE 1 UP PEAK

Example 1 is an office building with eight levels, and 100 persons per floor on upper levels. Level 1 is 5m high; the other floors are 3.8m high. The design requirement is for a 15% up peak handling capacity with an interval of 30 seconds or AWT of 18 seconds.

UPRTTC, General Analysis and Simulation calculations were performed. For the Simulation, *Elevate* was set up to generate traffic for 15 minutes and to run using an up peak dispatcher algorithm until all the passengers' journeys were complete. *Elevate's* default values were used for all other variables. The UPRTTC and General Analysis results for interval are given in Figures 3 and 4. The Simulation results for AWT are given in Figure 5.

The UPRTTC and General Analysis results for interval are almost identical. This is, as we would expect. Although the formulae are different, they are both valid RTT calculations; the General Analysis is more complex than the UPRTTC, but they are still both calculating probable number of stops, highest reversal floors, and so on.

Both UPRTTC and General Analysis give no results for one, two or three lifts. This is because the specified 15% handling capacity cannot be achieved without exceeding 80% Capacity Factor.

With a design interval of 30 seconds, four lifts at 1.6 m/s is the minimum specification choice based on these analyses.

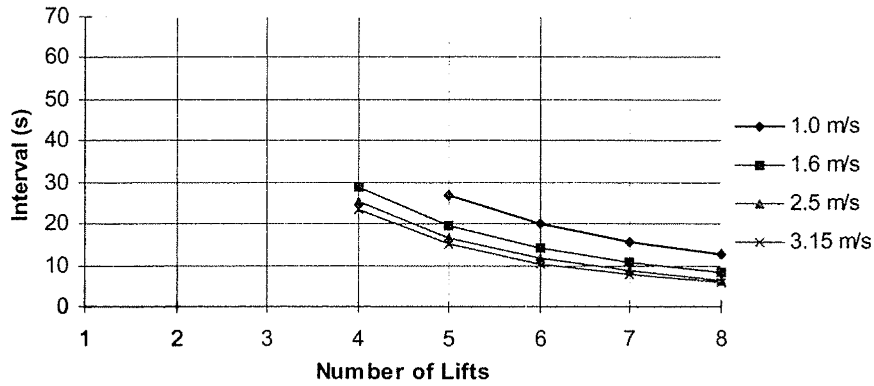

Figure 3 ***Example*** *1 Results: Interval calculated with Up Peak calculation*

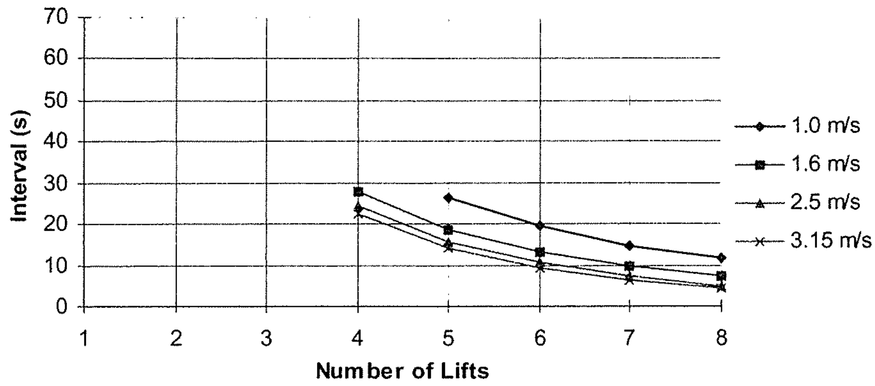

Figure 4 Example 1 Results: Interval calculated with General Analysis calculation

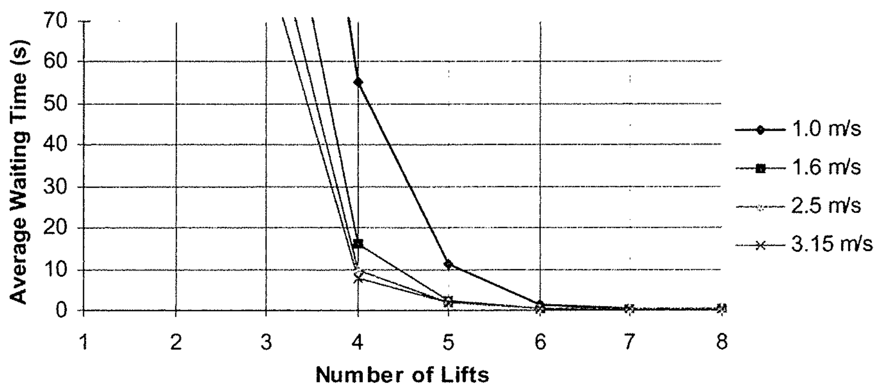

Figure 5 Example 1 Results: AWT calculated by Simulation

With simulation, all the configurations yield results (although some are beyond the scale of the graph in Figure 5). Where the traffic exceeds the handling capacity of the system, long queues form. The queues do not clear until the traffic levels drop (in this instance after 15 minutes). Although all the passengers are transported, their AWT is very high. With a design AWT of 18 seconds, four lifts at 1.6 m/s is again the minimum lift configuration needed to meet the design specification.

The results for five or more lifts show that the RTT calculations are pessimistic in this case. It is clear from observing the simulation that the over-capacity in the system combined with an efficient up peak parking policy results in there almost always being at least one lift parked at Level 1, waiting to receive the next call.

Up to this point the calculations have assumed a fixed capacity of 1250 kg. If we look at a range of capacities, Simulation requires the four 1.6 m/s lifts solution to have a minimum capacity of 1250 kg. The RTT calculations would allow a minimum capacity of 1000 kg.

As an aside, note that the performance benefits of choosing 1.6 m/s lifts in preference to 1.0 m/s lifts are significant. Further increases in speed provide increasingly marginal improvements. If you specify a high speed lift for a low-rise application, the lift rarely gets up to speed, and its high speed is wasted.

EXAMPLE 2 LUNCH PEAK

Example 2 is a demonstration of lunchtime traffic for the building described in Example 1. For the purposes of this example, we have estimated that there will be 5% up peak traffic, 5% down peak traffic and 5% inter-floor traffic.

The UPRTTC cannot model this type of traffic. The General Analysis results for interval are given in Figure 6, and Simulation results for AWT are given in Figure 7.

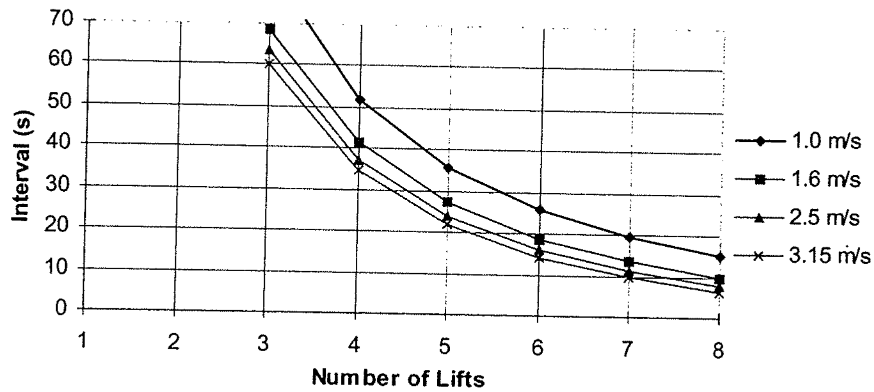

Figure 6 Example 2 Results: Interval calculated with General Analysis calculation

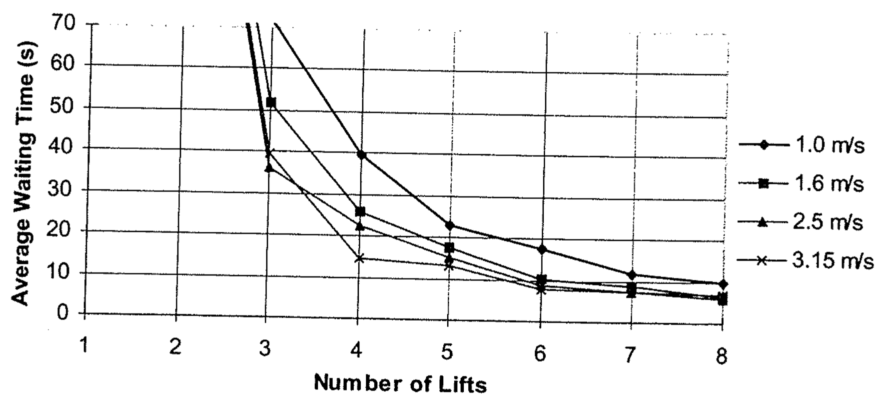

Figure 7 Example 2 Results: AWT calculated by Simulation

Note that although the total handling capacity (15%) is the same as for Example 1, the results for three lifts are better than for the up peak. There was insufficient capacity in a three lift system for 15% up peak handling capacity as everyone was getting into the lifts at Level 1. At lunch people are using the lifts to travel up as well as down, so there could be up to twice the number of people transported in each round trip. Because of this, lift systems have higher handling capacities during lunch peaks than they do in the mornings.

However, as previously noted (Peters et al 1996), people often have to wait longer for the lifts at lunch time. The four 1.6 m/s lifts selected in Example 1 for the up peak are, at lunch time, giving an interval of 41 seconds and an AWT of 26 seconds (which is an AWT/interval ratio of 63%).

The correlation between interval and AWT is better than for the up peak. Unlike for the up peak, we do not have empty lifts queuing at the ground floor when the system is under utilised. Again, an AWT/interval ratio of 60% is a reasonable approximation for solutions with well-utilised lifts.

EXAMPLE 3 MORNING PEAK IN HOTEL

Example 3 is an analysis of the four passenger lifts at Swisshotel, Zurich during Elevcon 98. At the time of the conference, the hotel's 347 rooms were 99% occupied with 427 people.

The building was surveyed during the busiest peak period, which is normally the morning in hotels. At that time the traffic was a combination of passengers to/from breakfast, exiting the building, and travelling to the conference facilities. A summary of the traffic travelling up and down the building is plotted in Figure 8.

The passenger traffic included porters with trolleys who take longer to load and unload the lifts; they also take more space. Because there is more than one type of traffic (people, and people with trolleys), simulation is the only tool we can use to model this traffic in full.

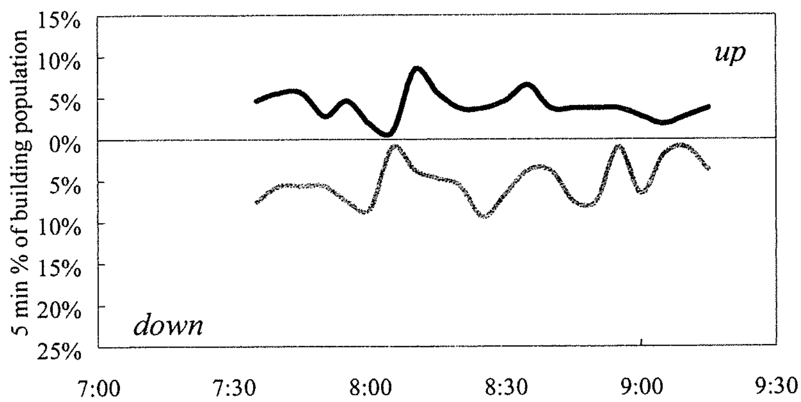

Figure 8 Peak traffic for Swisshotel survey

Using *Elevate* we were able to model the actual operation of the lifts. The AWT was approximately 24 seconds with the installed four 900 kg lifts at 3.15 m/s.

For comparison, we have modelled the installation with a range of speeds and numbers of lifts, as for examples 1 and 2. The results are given in Figure 9.

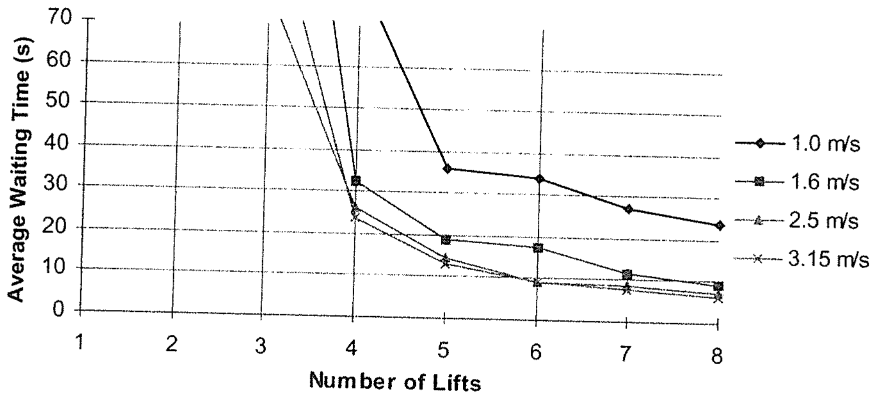

Figure 9 Swisshotel AWT calculated by Simulation

Notice that during this peak period, 3.15 m/s lifts provide virtually no benefit over 2.5 m/s lifts in terms of AWT. The lifts have to stop so frequently, that they are rarely running at full speed over significant distances.

6. DISCUSSION AND CONCLUSIONS

In this paper we have looked at three analysis techniques. The UPRTTC is a valuable benchmark calculation that has been with us for many years. The General Analysis calculation improves on the UPRTTC by allowing us to perform RTT calculations for any peak traffic flow.

Both the UPRTTC and General Analysis calculate an "average trip" by an "average lift" to determine RTT. Assuming the lifts are equally spaced, they extrapolate interval by dividing the RTT by the number of lifts. The UPRTTC and General Analysis give consistent results for consistent data. But the UPRTTC can only be used for up peak traffic, and the General Analysis can be applied to any peak traffic.

Simulation is more sophisticated, modelling the journey of every passenger, and calculating AWT. It is even more flexible than the General Analysis, allowing designers to consider off-peak traffic, changing traffic levels, mixed traffic types, and lifts of different specification (different speeds, capacities, floors served, etc.) in the same group.

Simulation provides results in terms of AWT rather than interval. The authors suggest, for the purposes of design, an AWT/interval ratio of 60%. RTT calculations are not always consistent with Simulation calculations, but will normally give similar "design solutions".

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BIOGRAPHY

Dr Richard D Peters is a Director of Peters Research Ltd, Secretary of the CIBSE Lifts Group, and a visiting lecturer on Lift Systems at UMIST. Dr Peters is well known for his lift traffic analysis techniques and software, which are applied internationally by leading consultants, lift companies and academics worldwide.

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