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# Measuring and Simulating Elevator Passengers in Existing Buildings

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**Key Words:** Simulation, survey, traffic analysis

**ABSTRACT**

Elevator traffic surveys are an essential part of understanding elevator passenger traffic in buildings, a prerequisite for good traffic analysis design. In this paper the authors describe how to: (i) perform a traffic survey using a manual count of passengers at the main lobby and in the cars; (ii) analyse the data measured; (iii) model the building surveyed in simulation. An example survey and analysis is presented, including a description of the software tools used to collect and process the data. Simulation results are shown to be consistent with the hall call analysis provided by the elevator control system.

## 1. INTRODUCTION

In order to predict the quality of service for new and modernised elevator installations, it is necessary to make assumptions about how many people will use the elevators at different times of the day. Knowing this information, we can simulate a range of different scenarios with different elevator configurations and make informed design decisions.

The purpose of this paper is to describe and to demonstrate a methodology for measuring traffic in buildings, so that the survey data can be (i) generalised and applied to other buildings and (ii) used to model the existing elevator traffic in simulation.

## 2. TRAFFIC ANALYSERS

Traffic analysers are sometimes linked to or built into elevator control systems, and record the time every landing and car call is made and cleared. They analyse this data and provide a range of performance results and graphs. Traffic analysers give a good indication of the elevator system's performance, but very limited information about the actual passenger traffic flow. For example, Figure 1 shows the results of a traffic survey carried out with a traffic analyser. The upper section of the graph shows the up hall calls placed on the system. The lower part shows the down hall calls. Figure 2 shows the corresponding people count. The upper section of the graphs records people travelling up the building. The lower section of the graph records people travelling down the building. The hall call information gives no indication of the up peak in the morning or at the beginning of lunch measured by observers counting people. This is because in up peak traffic, a single hall call at the entrance level could correspond to a whole carload of passengers.  At the same time, a down call at upper floors may correspond to a single passenger.

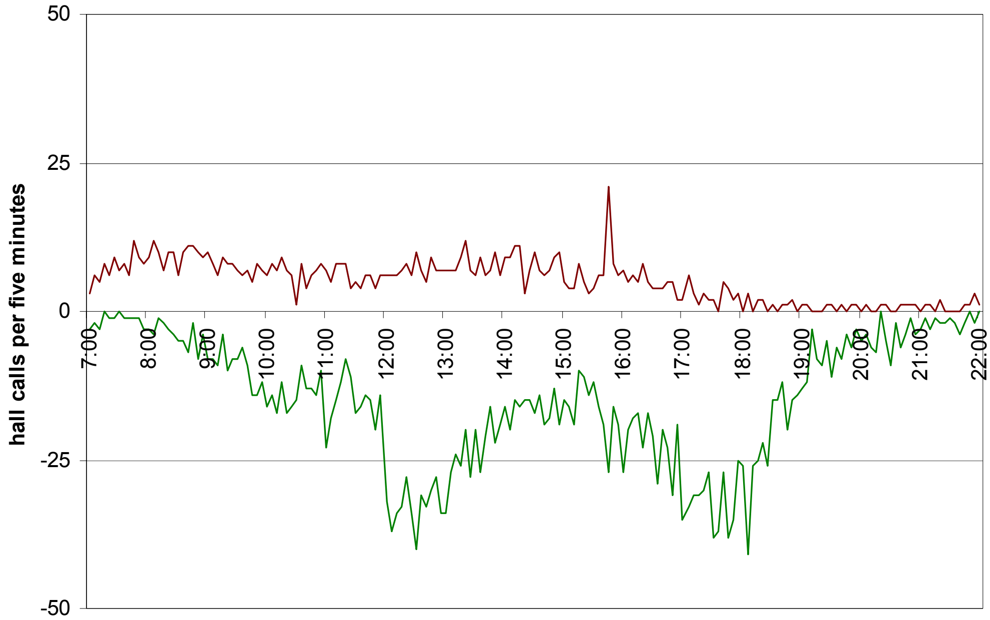


***Figure 1   Up and down calls measured by a traffic analyser***

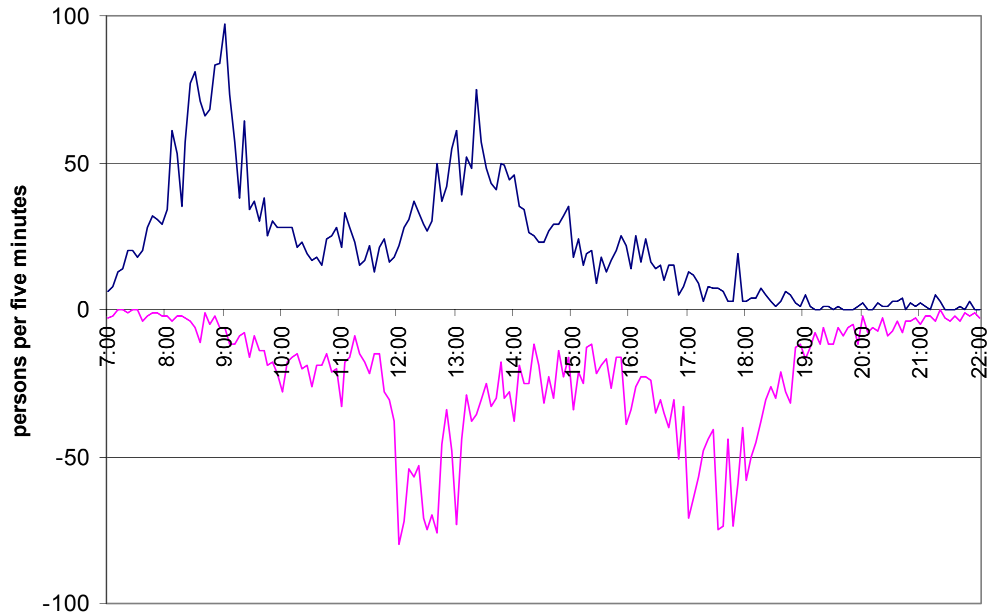


***Figure 2   Up and down traffic measured by survey***

To provide useful information about passenger demand, surveys must count or estimate the number of people transported as opposed to the number of calls registered.  Some suppliers [1] have used information from passenger detection systems (light beams) and load weighing to provide this information.  With destination control, every passenger is assumed to register his or her own call; this too can yield much more valuable estimates of the actual passenger traffic flow. However, in the vast majority of buildings, this type of traffic monitoring is not available, which is why there is a need for manual passenger surveys.

## 3. DESCRIBING TRAFFIC

In many office buildings it is unlikely that all the population will be present on any day [2]. Thus it is important to express passenger demand as a percentage of the "observed population". This normalises results for office buildings so that they can be applied to other buildings (normalising traffic for other building types will be addressed in future publications). An example plot of observed building population is given in Figure 3.

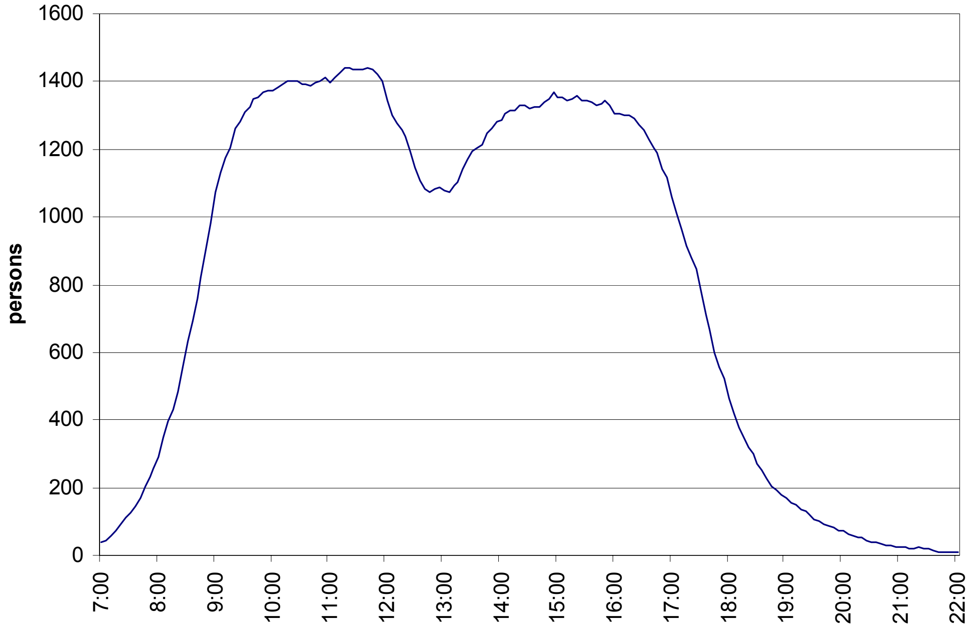


***Figure 3 Observed building population***

Passenger Demand can be divided into three components:

| | |
|---|---|
| % incoming | the part of the total traffic that corresponds to passengers arriving at the entrance floor(s), and travelling up the building, or down to any floors below the entrance floor(s). |
| % outgoing | the part of the total traffic that corresponds to passengers arriving at floors above (or below) the entrance floor(s), and travelling to the entrance floor(s). |
| % interfloor | the part of the total arrival rate that corresponds to passengers travelling between floors other than the entrance floor(s). |

To measure passenger demand, a lobby survey is required to establish the predominant incoming and outgoing traffic flow. An in-car survey is required to sample the interfloor traffic component.

## 4. CARRRYING OUT THE SURVEY

### 4.1 Survey Times

An appropriate survey time for professional office buildings is 7 am to 10 pm. Any discrepancy between the people counted in and out is assumed to be the number of people in the building when the survey team arrived or left. Using video recordings, 24-hour surveys have been performed to confirm that this is a valid approach. Based on a regular 9:00 to 5:30 hrs working day with 12:30 to 13:30 hrs lunch, the recommended times for interfloor surveys are 08:30 to 09:30 hrs, 10:30 to 11:30 hrs, 12:30 to 13:30 hrs, 14:30 to 15:30 hrs and 17:00 to 18:00 hrs. Working times do vary, so due consideration should be given to local behaviour.

### 4.2 Preparation

Once permission to undertake the survey has been obtained, a pre-survey visit should be carried out. The survey team will require an unrestricted view of the elevator lobby area and to have sight of people entering and alighting the cars for counting. If the building is under elevated, large queues may be experienced as passenger loading is limited by the available handling capacity. In these situations, a better estimate of demand is obtained by counting people into and out of the elevator lobby. Observation positions should be as unobtrusive as possible and must not obstruct corridors and thoroughfares. If laptop computers are to be used for logging traffic, a power socket will normally be required. Light laptops with long battery life are needed if in-car surveys are to be carried out using logging software.

The pre-survey visit should be used as an opportunity to highlight and assess any health and safety issues e.g. location of survey team, trip hazards caused by cables. These issues should be discussed with building management and measures taken to resolve any issues.

In planning the size of the survey teams allow for continuous counting at the main entrance lobby all day. If there are multiple entrance floors, continuous counting will be needed at each of these floors. Also consider a peak time lobby survey for high use floors, such as restaurants. Allow for breaks and for working in shifts so that staff do not need to be at the building for the whole day. Because of the volume of traffic in large installations, e.g. 8 car groups, it can be necessary to schedule 2 people to be counting simultaneously at the main entrance floor during the lunchtime peak.

The choice of survey day and times should be reviewed with building management. It is prudent to avoid public and school holidays. Also, the first and last day of the working week can be less busy due to people taking extended weekends. It is worthwhile choosing two survey days, one for the main team, and a second date to return with one or two people only, just to measure peaks and to note any deviation from the main survey measurements. Awareness to transportation, e.g. train stations or any particular traffic issues, will help interpret results.

The net useable area and nominal building population can be used in conjunction with the measurement of observed population to establish the occupancy and absenteeism. Details of the elevators, which floors they serve, their size, capacity, door times and speed will be needed if the intention is to simulate the existing installation.

### 4.3 Data Collection

Data collection is conventionally in 5-minute intervals. Forms can be prepared to record the data [3]. Electronic equivalents of traffic survey forms are provided with Elevate [4]. The benefits of logging software are that each event is time stamped so that the observer does not have to keep referring to his or her watch. Also, processing of the data can be automated (currently Elevate customers have to send their logging files to Peters Research Ltd for processing). Screen shots of Elevate Count (lobby and in-car survey software) are given in Figure 4. Full details of their operation are provided in the Elevate user manual.

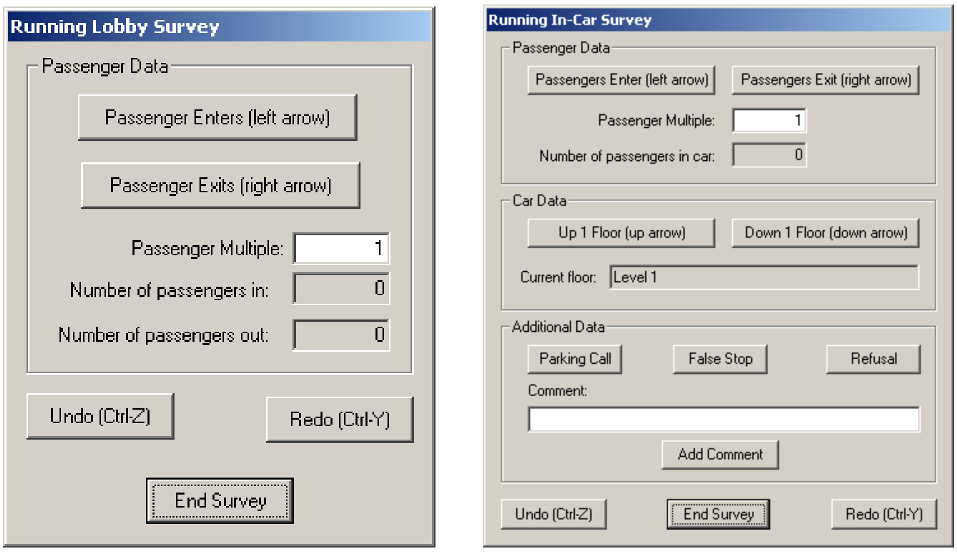


*Figure 4 Elevate Count, lobby and in-car survey software*

## 5. DATA PROCESSING

### 5.1 Lobby Survey

The lobby survey data is simple to process. The data is divided into 5-minute intervals, as demonstrated in Figure 5 and the corresponding Table 1.

```
00013 | 07:29:49 | ENTER_LOBBY | 1.0
00014 | 07:31:08 | ENTER_LOBBY | 1.0
00015 | 07:31:44 | ENTER_LOBBY | 1.0
00016 | 07:31:54 | EXIT_LOBBY | 1.0
00017 | 07:32:49 | ENTER_LOBBY | 1.0
00018 | 07:32:56 | ENTER_LOBBY | 1.0
00019 | 07:34:22 | ENTER_LOBBY | 2.0
00020 | 07:35:01 | ENTER_LOBBY | 1.0
00021 | 07:37:25 | ENTER_LOBBY | 1.0
00022 | 07:38:39 | ENTER_LOBBY | 1.0
00023 | 07:39:15 | ENTER_LOBBY | 1.0
00024 | 07:40:56 | ENTER_LOBBY | 1.0
00025 | 07:41:25 | ENTER_LOBBY | 1.0
00026 | 07:42:44 | ENTER_LOBBY | 1.0
00027 | 07:43:11 | ENTER_LOBBY | 1.0
00028 | 07:45:14 | EXIT_LOBBY | 1.0
00029 | 07:45:56 | ENTER_LOBBY | 1.0
00030 | 07:45:58 | ENTER_LOBBY | 2.0
00031 | 07:45:58 | ENTER_LOBBY | 1.0
00032 | 07:50:01 | ENTER_LOBBY | 1.0
```

*Figure 5 Sample lobby survey data*

*Table 1 Lobby survey results table*

| Time | Lobby Incoming (persons per 5 mins) | Lobby Outgoing (persons per 5 mins) |
|---|---|---|
| 7:30 | 6 | 1 |
| 7:35 | 4 | 0 |
| 7:40 | 4 | 0 |
| 7:45 | 3 | 1 |

## 5.2 In-Car Survey

Analysis of the in-car survey data is more complex, as the observer is seeing a sample of incoming, outgoing and interfloor traffic. The first exercise is to identify the interfloor traffic, which is the component not seen by the lobby survey observer. Figure 6 illustrates how to determined which passengers contribute to interfloor traffic.

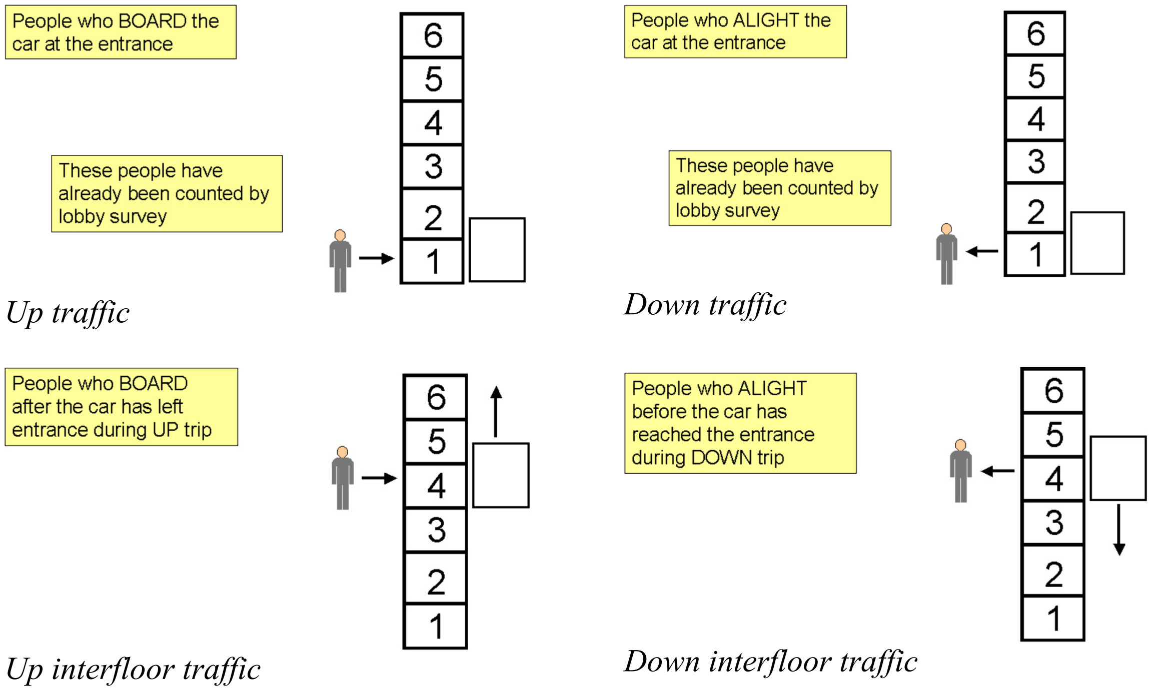


***Figure 6 Illustration of the identification of interfloor traffic for an in-car survey***

On this basis, the log of interfloor traffic can be processed, as shown in Figure 7. Note that as people are counted both into and out of the cars, 14 events in the log correspond to 7 people.

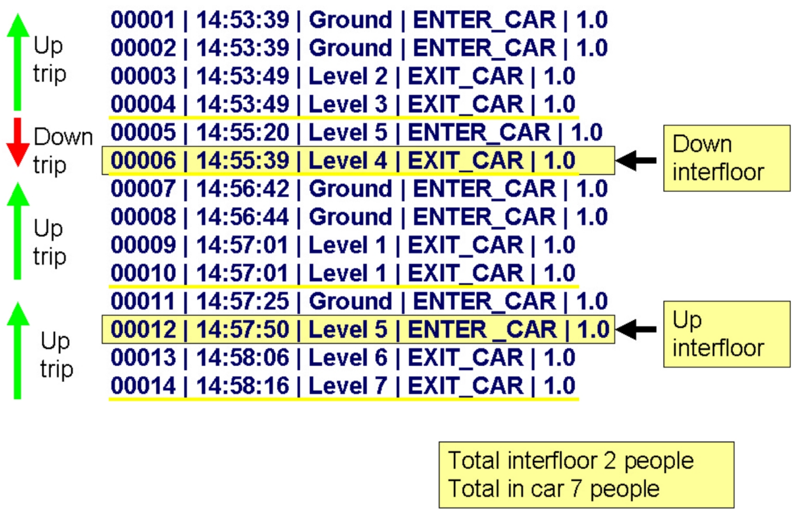


***Figure 7 Sample processing of in-car survey data***

### 5.3 Calculation of Demand

Assume the interfloor traffic, as a proportion of lobby traffic, is constant throughout each one hour in-car survey period. On this basis, the lobby survey data can be scaled to include the interfloor traffic, which has been sampled by the in-car survey. In persons per five minutes:

$$\text{Passenger\_Demand} = (\text{Lobby\_Incoming} + \text{Lobby\_Outgoing}) \times \frac{\text{Total\_in\_car}}{\text{Total\_in\_car} - \text{Total\_interfloor}} \quad (1)$$

In the periods between the one hour in-car surveys, assume the data is consistent, i.e. the in-car analysis from 08:30 to 09:30 hrs data is also valid from 9:30 to 10:00; the in-car analysis from 10:30 to 11:30 hrs data is also valid from 10:00 to 10:30.

Then determine the division of the total passenger demand between incoming, outgoing and interfloor traffic:

$$\%\text{\_incoming} = 100 \times \frac{\text{Lobby\_Incoming}}{\text{Passenger\_Demand}} \quad (2)$$

$$\%\text{\_outgoing} = 100 \times \frac{\text{Lobby\_Outgoing}}{\text{Passenger\_Demand}} \quad (3)$$

$$\%\text{\_interfloor} = 100 \times \frac{[\text{Passenger\_Demand} - (\text{Lobby\_Incoming} + \text{Lobby\_Outgoing})]}{\text{Passenger\_Demand}} \quad (4)$$

Finally, express the passenger demand as a percentage of the observed building population:

$$\%\text{\_Passenger\_Demand} = 100 \times \frac{\text{Passenger\_Demand}}{\text{Observed\_Population}} \quad (5)$$

This yields a summary table of demand, as per the example in Table 2.

***Table 2 Sample results for passenger demand***

| Time | % Passenger Demand | % Incoming | % Outgoing | % Interfloor |
|---|---|---|---|---|
| 8:45 | 5.2% | 90.2% | 6.6% | 3.1% |
| 8:50 | 6.1% | 94.6% | 2.3% | 3.1% |
| 8:55 | 6.4% | 90.4% | 6.5% | 3.1% |
| 9:00 | 7.4% | 91.2% | 5.6% | 3.1% |
| 9:05 | 6.1% | 83.2% | 13.7% | 3.1% |
| 9:10 | 4.9% | 80.0% | 16.8% | 3.1% |
| 9:15 | 5.2% | 90.2% | 6.6% | 3.1% |

## 6. SIMULATION OF THE TRAFFIC

To transfer the data to Elevate or other simulation programs, distribute the observed population across the upper floors according to the ratio of floor areas. Then use the traffic generating utilities to create arrival rate and destination probability tables for each 5-minute period based on input of % demand and % incoming, outgoing and interfloor. Figure 8 shows the resulting Elevate plot for the passenger demand for the building referred to in section 2.

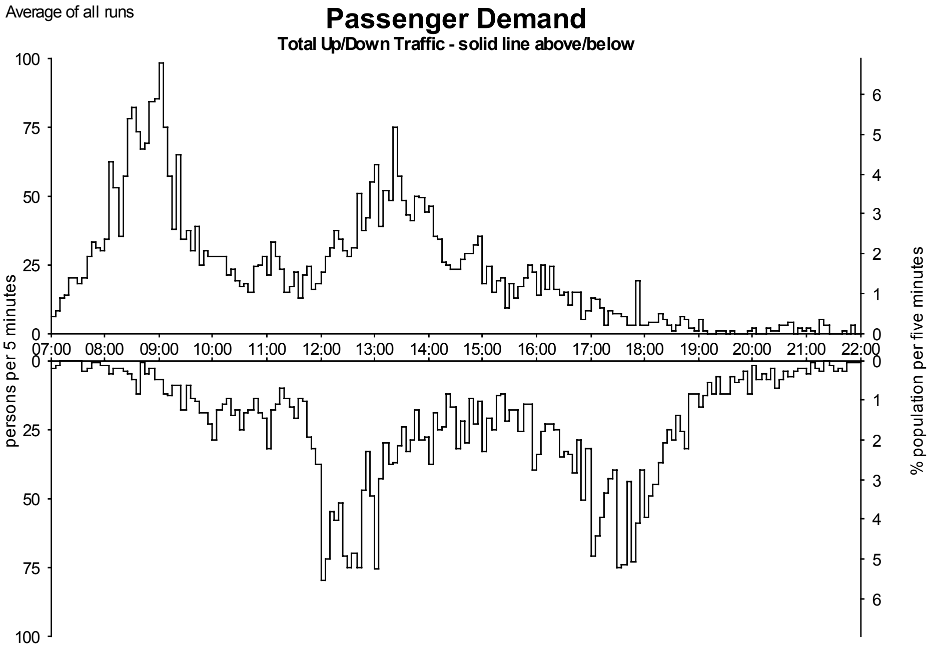


***Figure 8 Elevate plot of passenger demand***

Figure 9 plots passenger activity, which shows incoming, outgoing and interfloor traffic stacked on top of each other.

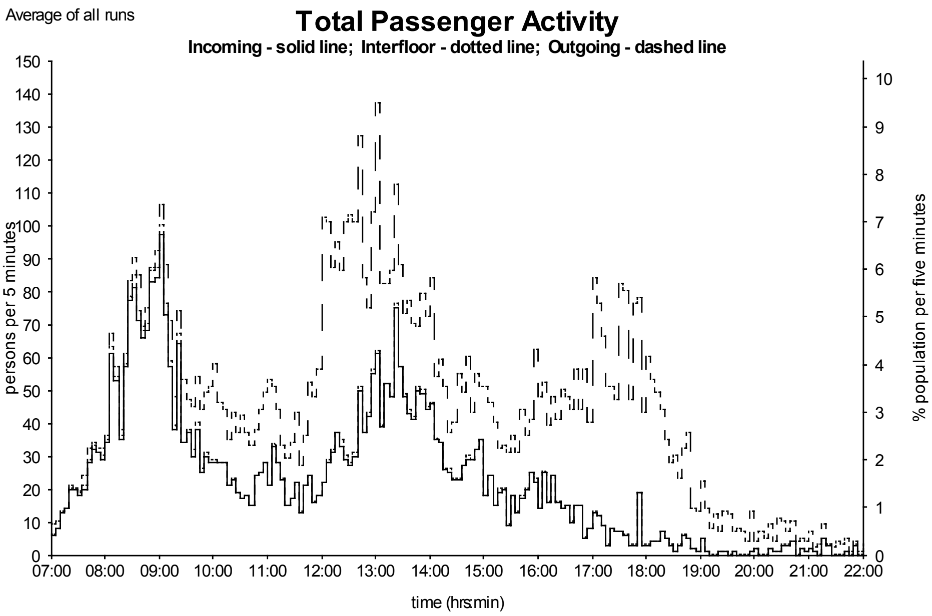


***Figure 9 Elevate plot of passenger activity***

The building is multi-tenancy with negligible interfloor traffic and an observed population of 1442 people. This is a high-rise bank so there is no stair contribution to incoming and outgoing traffic. The peak demands recorded were as summarised in Table 3.

*Table 3   Peak passenger demand results for sample building*

| | Peak Passenger Demand (% observed population) | Incoming (% of demand) | Outgoing (% of demand) | Interfloor (% of demand) |
|---|---|---|---|---|
| Up peak | 7.4 | 91.2 | 5.6 | 3.1 |
| Lunch peak | 9.4 | 44.9 | 53.8 | 1.3 |
| Down peak | 6.2 | 14.6 | 79.9 | 5.5 |

To demonstrate consistency between simulation and measurement, an Elevate simulation has been run. Simulation results are normally presented in terms of waiting time and time to destination, but simulation software can also count hall calls. Figure 10 show the simulation results for up and down calls, for comparison with Figure 1. The results show a good correlation. The down calls peaks are marginally higher than expected; this is probably due to some passengers travelling in groups in the actual installation, and less grouping in the simulation.

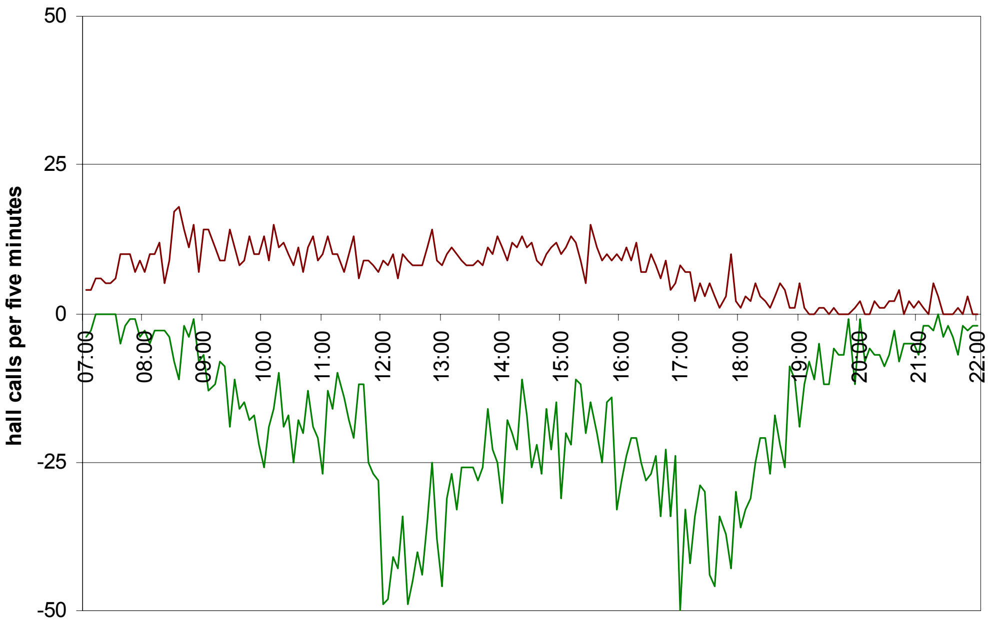


*Figure 10 Up and down calls measured in simulation*

## 7. FURTHER CONSIDERATIONS

### 7.1 Stair Usage

In a low rise building stair usage can also be monitored for a better understanding of the demand. Figure 11 is a plot of the passenger demand in a single tenancy low-rise building combining both the elevator and stair traffic. Without access to the stairs, this would have been the demand on the elevators.

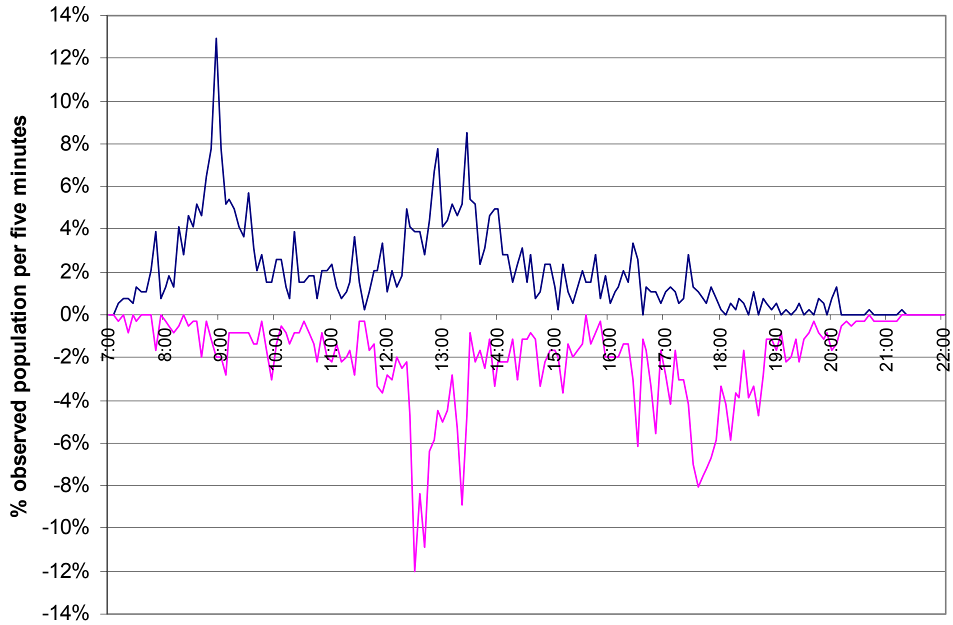


***Figure 11 Combined elevator and stair passenger demand for in sample low-rise building***

However, in this building, there is easy access to stairs, and the occupants are inclined to use them. Figure 12 shows the actual demand on the elevators.

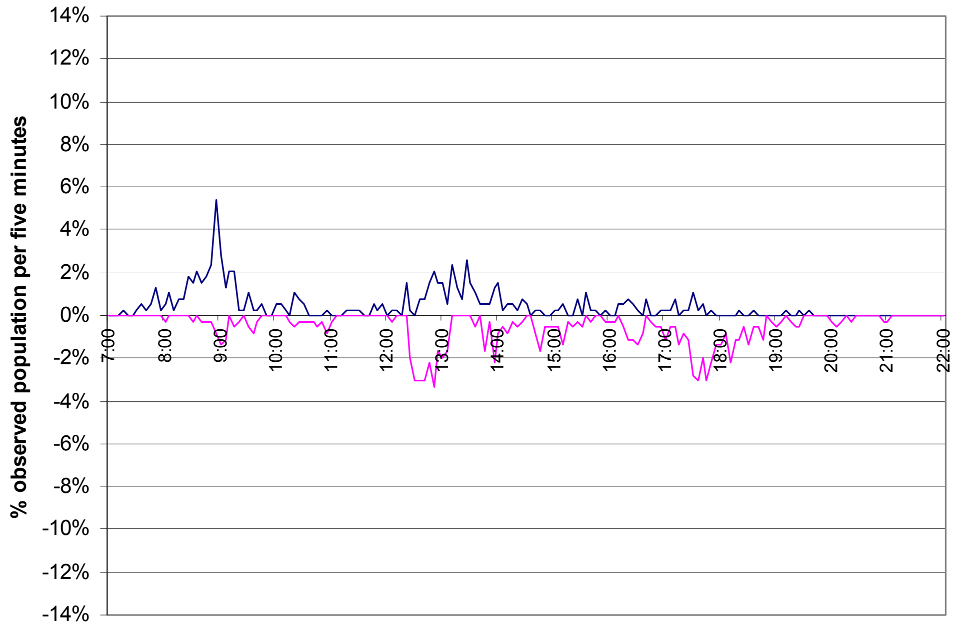


***Figure 12 Elevator demand in sample low-rise building***

## 7.2 Multiple Entrances

To manage multiple entrance floors, a lobby survey needs to be carried out on each of the entrance floors. The relative demand between the entrance floors is known as entrance level bias. Figure 13 plots the entrance level in a building that has two entrance levels.

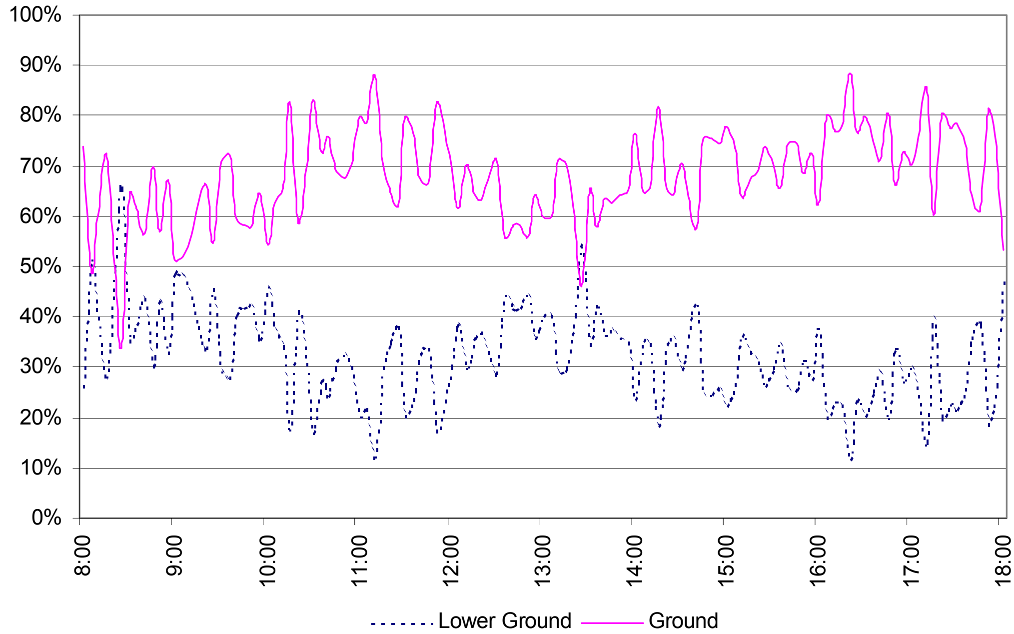


***Figure 13 Entrance level bias for building with multiple entrances***

## 7.3 Car Loading

In-car survey data can also be used to plot car occupancy. Elevate Count allows for the logging of refusals, i.e. where a car is so crowded that a passenger decides not to load, preferring to wait for the next car. This can be used to establish capacity factor. In the example given in Figure 14, the 15th person refused to load the 23-person car. Therefore 14 persons was the maximum loading for the 23-person car, yielding a capacity factor 61%.

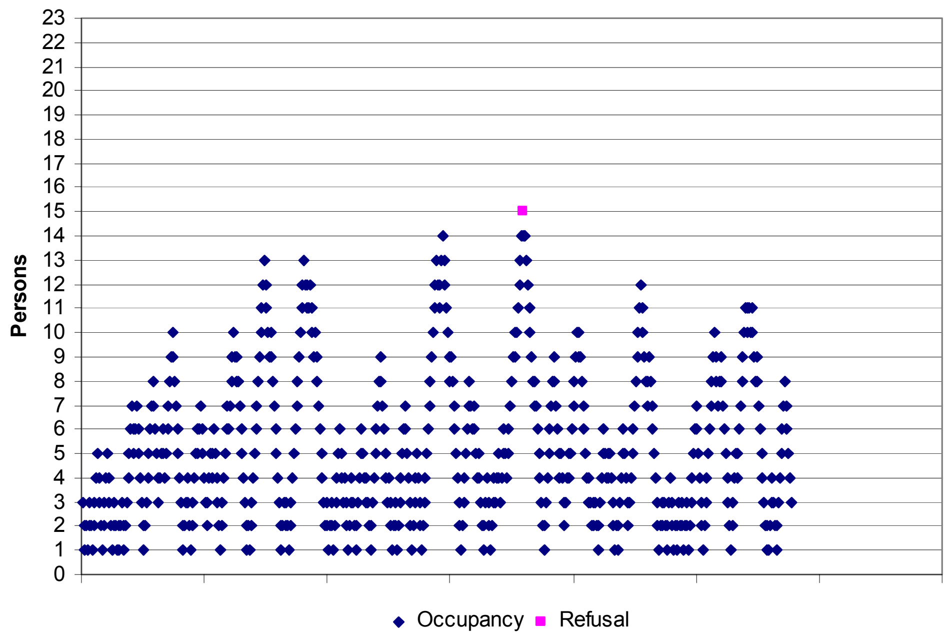


***Figure 14 Occupancy scatter diagram***

## 8. CONCLUSIONS

A comprehensive study of elevator traffic demand is a major task requiring a team of observers. However, the data it yields is valuable. With a model of the existing traffic in a building, we have the basis for assessing the benefit of modernisation improvements using simulation. The authors would like to encourage others to adopt the survey methodology described in this paper so that, as an industry, we present traffic survey results consistently. To this end, the authors will provide assistance and guidance for those prepared to share their survey results. As we continue to study more buildings, we will be in a better position to improve our design criteria for new buildings.

Finally, for those who would take the results presented in this paper and use them immediately as a basis for reducing their current peak 5-minute handling criteria, beware! The risks are that (i) the buildings presented are not worst case (ii) actual elevator performance is not as good as assumed in calculations, (iii) elevators may occasionally be out of service during peak times. Departing from conventional criteria for elevator selection and reducing the number of elevators for new buildings introduces risk. Before lowering design requirements, designers must understand and communicate the issues, adopting strategies that mitigate the risk of long queues, crowded cars, and unacceptably long passenger waiting and transit times.

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## BIOGRAPHICAL DETAILS

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