This paper was published by the Building Services Engineering Research and Technology Journal Volume 32 No 2 (2011). This web version © Peters Research Ltd 2011.

The Appraisal of Lift Passenger Demand in Modern Office Buildings

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Abstract

The number of passengers wanting to use lifts to travel to and from the lobby and between floors in a building has a significant effect on the quality of lift service experienced by each passenger. The traditional assumptions of lift passenger demand in office buildings are compared to measurements taken in modern buildings. The differences between traditional and modern patterns of passenger demand in office buildings are discussed. The significance of these differences on lift system design is explored. In office buildings surveyed, the daily pattern of passenger demand repeats itself with a high degree of consistency; buildings can be described as having their own demand 'signatures'.

***Practical Applications*:** Designing lift systems based on modern traffic patterns and traffic levels will result in systems with characteristics that are different from those designed using traditional traffic expectations. Applying the traffic data in this paper will result in a more accurate prediction of a lift system's performance. Control system designers can use the traffic data to design dispatcher algorithms that can better respond to modern traffic conditions.

1. INTRODUCTION

The quantity of passengers to be transported by a lift system is a primary consideration in lift 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 lifts required to provide a proper and efficient lift service may need to be revised based on these findings. These changes in lift 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 lifts 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.[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[1]

Figure 2 plots passenger demand based on a similar pattern of office demand developed by Barney.[2,3,4] The patterns of passenger demand presented by Strakosch and Barney are very similar. They have a pronounced up-peak in the morning, a pronounced down-peak in the evening, two small lunchtime up-peaks, and two small lunchtime down-peaks. Additionally, periods of balanced two-way traffic can be seen.

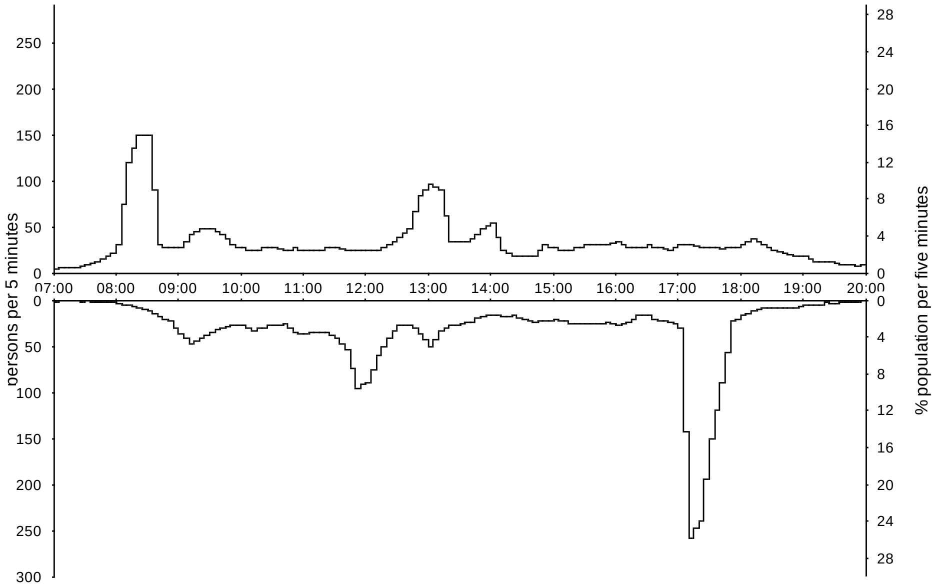

Figure 2 Passenger demand based on presentation by Barney [2,3,4]

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 period.

It was generally believed that the most demanding traffic type was the morning up-peak. This belief was reinforced by research conducted by Barney that showed lifts have between 20% and 60% more handling capacity during non up-peak conditions.[4] It has been assumed by many in the lift industry that most office buildings have a pattern of passenger demand similar to those in Figures 1 and 2. Papers have been written about how lift dispatchers should handle the different types of traffic apparent during the working day: up-peak, down-peak, lunch and balanced two way.[5] Additional papers have been written about methods either to predict or to detect the type of traffic that existed so that the appropriate dispatching algorithm could be applied.[6] 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 a passenger demand pattern that existed over forty years ago is applicable to a present day building. These changes are discussed further in Section 5.

3. MODERN BUILDINGS

3.1 Traffic Patterns

How people use lifts and the traffic has changed since 1923, when Basset Jones published formulae for the expected number of stops a car would 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'.[7] In work-related buildings occupied during the day, 'the busiest period appears to be over the lunch period'. In 2002, Powell, discussing modern office buildings states 'two-way traffic at noontime is often a more severe test of elevators than up-peak'.[8]

In 2000 Siikonen presented a traffic pattern that represents traffic measured in a modern installation.[9] Siikonen presented data as a stacked area graph, but for consistency with Figures 1 and 2, the same data is presented in Figure 3 showing incoming and outgoing traffic separately.

This pattern is quite different from the traffic pattern presented by Barney and 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. Both the Barney and Strakosch lunch periods show 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?'

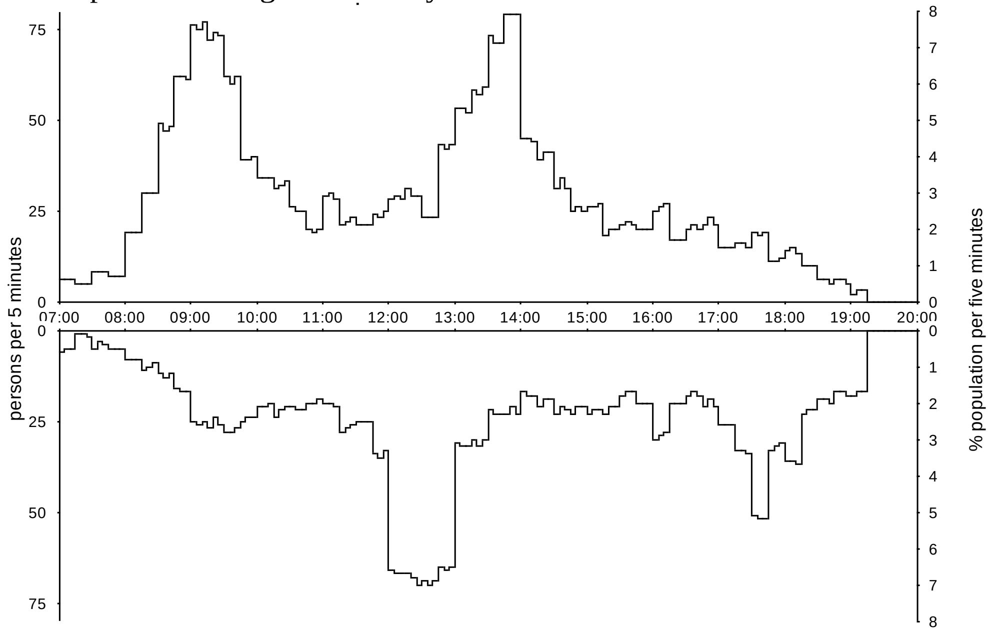

Figure 3 Passenger demand based on presentation by Siikonen [9]

In order to gain a better understanding of modern lift 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 lifts in a corporate headquarters building was gathered electronically.

3.2 MANUAL COUNTS

Figure 4 shows the results of lift traffic surveys for seven separate groups of lifts.[10] The surveys were undertaken applying a methodology defined by Peters and Evans.[11] The passenger demand is expressed as a percentage of 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.

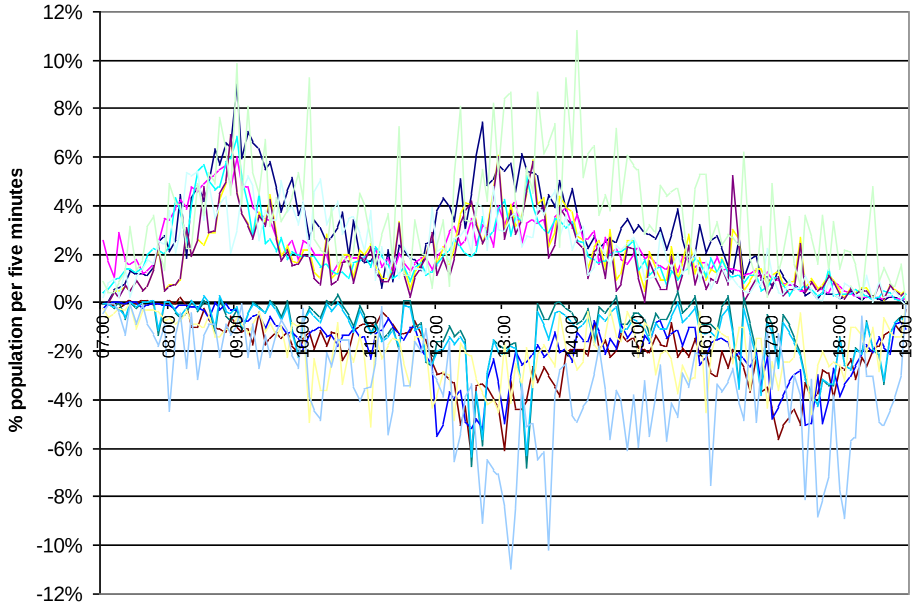

Figure 4 Passenger demand based on manual traffic surveys [10]

3.3 AUTOMATIC COUNTS

It is difficult to count automatically the number of passengers using lifts with conventional control systems which have up and down call buttons on the landings as they generally only count calls[2], and there is often more than one person behind a call. Some suppliers address this by supplementing the call information with information available from load weighing devices and photocells. With a destination control system the analysis is much easier as each passenger registers which floor they want to travel to on the landing. A destination control system based on the ETD algorithm was used to log the operation of the lifts including every destination call.[12] The logged data was replayed in the Elevate™ simulation program mapping destination calls to people, resulting in an estimate of passenger demand.[13] As each person is time stamped, the simulation program, as part of its regular functionality, can convert this list of people into a plot of passenger demand. It can also re-play the operation of the lifts, either as logged, or as a simulation using the measured passenger demand as an input to the simulation. In simulation, the dispatcher and other parameters can be changed to assess the benefits of enhancements.

Figures 5-7 illustrate the estimated passenger demand for the three groups of passenger lifts (low, mid and high rise) in a corporate headquarters building in the USA. The data in these figures represents a single day. Data at this building has been collected daily for over three years.

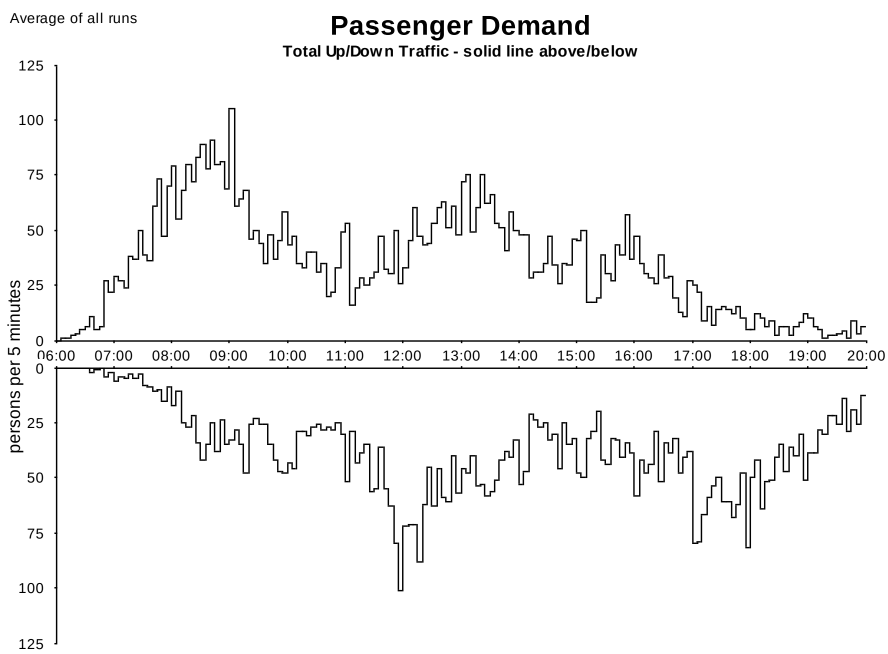

Figure 5 Low rise passenger demand

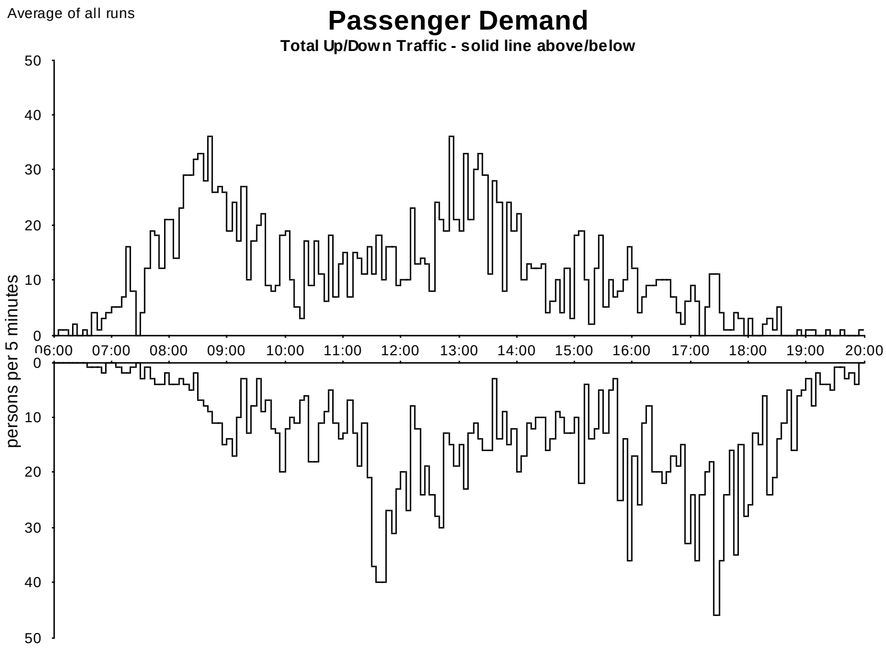

Figure 6 Mid rise passenger demand

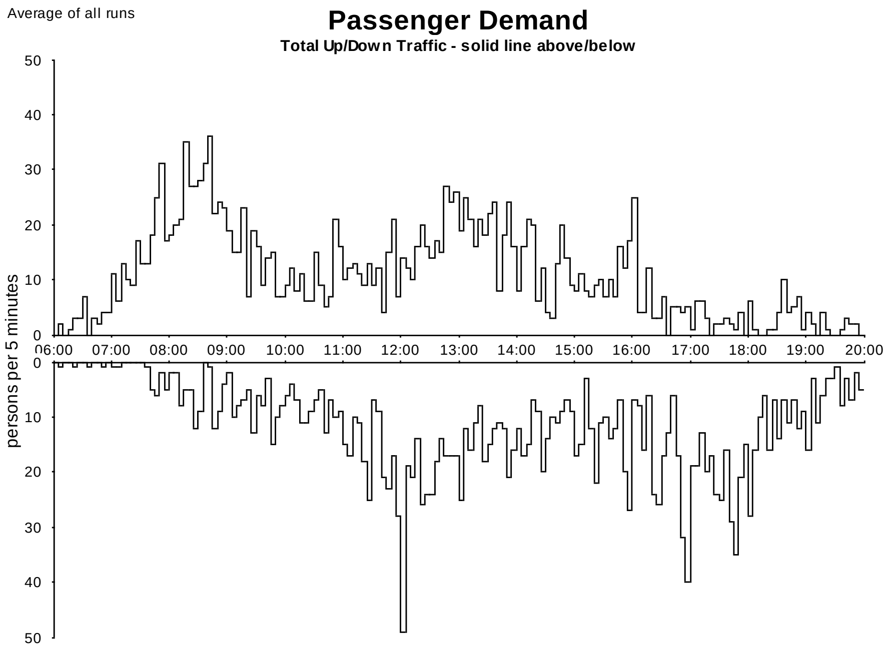

Figure 7 High rise passenger demand

Plotting data for a whole week demonstrates a high level of consistency in passenger demand, as illustrated by Figures 8-10. Each group has its own recognisable passenger demand pattern or 'signature'. Even within the same building, passenger demand can vary between the different lift groups.

Knowing that the passenger demand is consistent day to day is a valuable for information for designers of lift dispatchers.

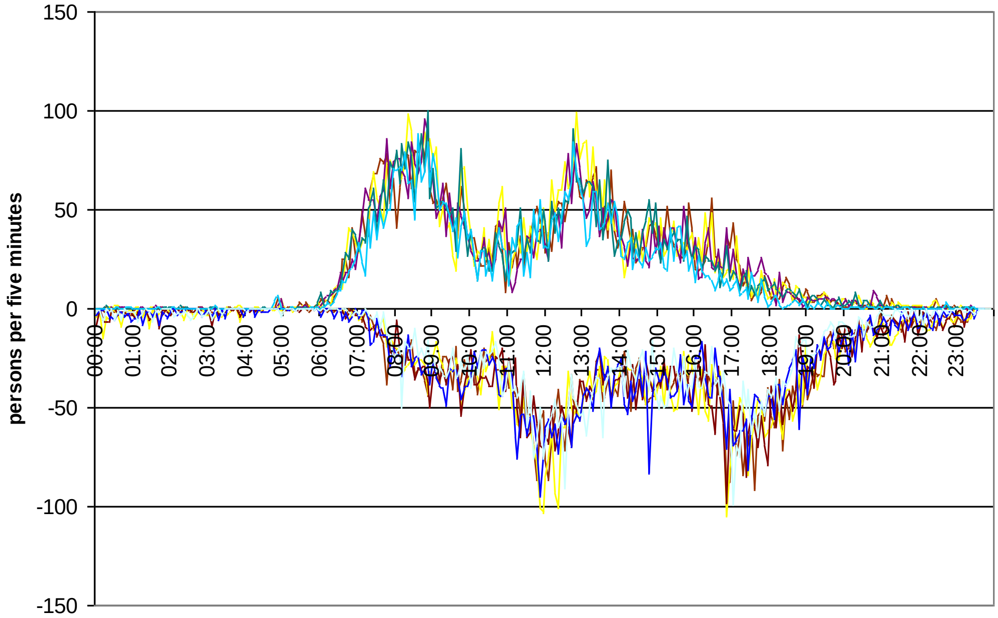

Figure 8 Low rise passenger demand signature

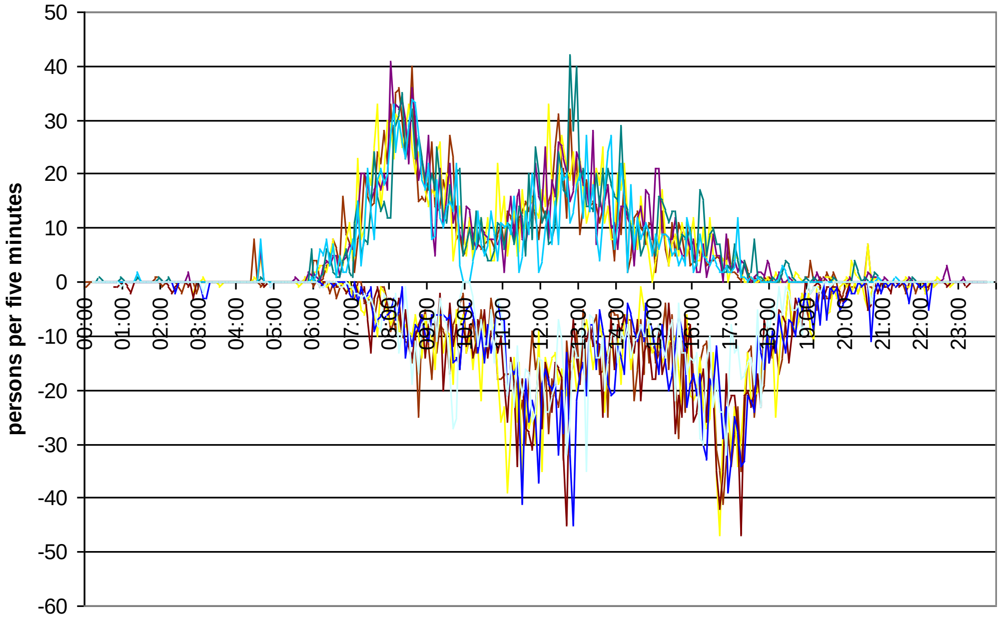

Figure 9 Mid rise passenger demand signature

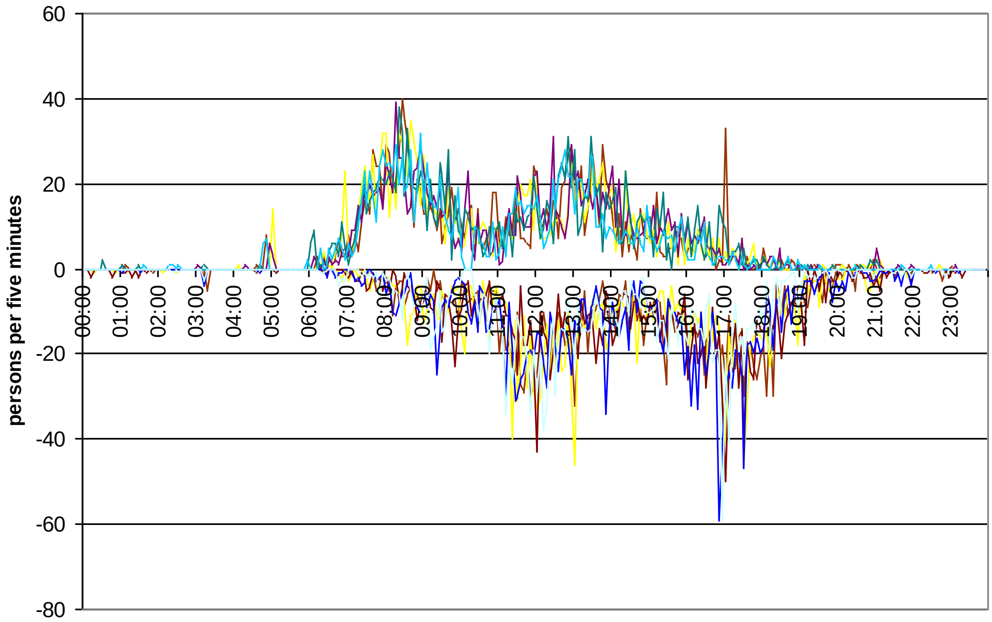

Figure 10 High rise passenger demand signature

During the banking crisis in the US many banks became insolvent and were subsequently acquired by other financial institutions. The office building where the automated data was collected was the headquarters building of one such bank. In October of 2008, the ownership of this bank changed.[14] The acquisition has resulted in a reduction of lift usage. The daily reports from this building record the number of passengers who use each bank of lifts.

On Tuesday May 20, 2008, 11574 passenger journeys were counted by the low rise bank of lifts between 06:00 in the morning and 20:00 in the evening. One year later, on Tuesday 19 May, 2009, 8631 passenger journeys were counted during the same time period. Even though almost 3000 fewer people used the lifts, the shape of the traffic pattern remained very similar. The traffic patterns recorded, either manually or automatically, and whether in the USA, the UK, or the UAE produced traffic signatures that are more similar in appearance to the Siikonen traffic pattern than the Strakosch profile.

4. CHANGES IN TRAFFIC PATTERNS

4.1 Up-peak traffic

In modern buildings there is often a significant amount of outgoing traffic during the morning incoming up-peak. A major contributor to this is people travelling to the main lobby or to a staff restaurant to purchase food and drink. A common practice is for a person to arrive for the first time at their desk after taking the lift up as they want to be seen as having arrived by their superiors and co-workers. They then take the lift back down, make their purchases and finally refreshments in hand, return to their workstation by taking the lift up.

This process involves two incoming and one outgoing trip.

The trend to ban smoking in public and work places has also been noted by building managers and during manual surveys to increase the outgoing demand during the morning incoming up-peak period.

Data gathered from the manual surveys and automatic counts has shown that on average the mix of traffic in modern buildings during the morning up-peak was found to be approximately 85% incoming, 10% outgoing and 5% interfloor.

4.2 LUNCH PEAK TRAFFIC

Siikonen explains part of the differences from Barney and Strakosch's classical representations by stating 'Flexible working hours creates a heavy down-peak before lunch hour'.[9]

The 'lunch hour' is actually nearer two hours. It is not unusual for the incoming traffic and outgoing traffic at lunchtime to be of the same order of magnitude as the incoming traffic in the morning up-peak, and the outgoing traffic during the evening down-peak.

Eating habits have changed over the years. It is now less common to bring a packed lunch to eat at your desk. All the major office buildings surveyed were in close walking distance of a range of eat-in and take-away restaurants. Also many had dedicated staff restaurants. The tendency nowadays is for staff to visit in-house facilities or take-away outlets and then return to continue working. This increases demand over the lunch period.

In 1970 US Citizens spent $6 billion on fast food.[15] By 2006 the money spent increased to $163.5 billion.[16] Even adjusting for inflation, it is evident there is an increasing trend towards using food outlets. The story in the UK is similar with households now spending more money on eating out than on buying food to eat at home.[17]

On average, the mix of traffic in modern buildings during the busiest part of lunch was found to be 45% incoming, 45% outgoing and 10% interfloor.

4.3 AFTERNOON AND DOWN-PEAK TRAFFIC

None of the groups surveyed have the sharp down-peak that is seen in the Barney and Strakosch pattern. A sharp down-peak would be expected in buildings with people who have strict working times. This is unusual in modern office buildings with professional workers. A significant portion of companies now have extended business hours as they operate across international time zones.

There is often sustained activity late afternoon. The afternoon up traffic may be related to people returning to the office after visiting clients. Some traffic may also be attributed to couriers such as FedEx, DHL and UPS. DHL began shipping documents from San Francisco to Honolulu in 1969,[18] while FedEx started operations in 1973.[19] With the growth of multi national companies and global business operations demand for the faster transfer of documents and goods has increased. The traffic generated by these couriers did not exist when the Strakosch and Barney patterns were developed.

4.4 A CHANGING WORKFORCE

The use of computers has changed the profile of the workforce. Previously, office workers included many people dedicated to clerical tasks. For example, typing pools were common, but in a modern building these no longer exist. People generate their own correspondence using email and word processing programs. Clerical workers have been replaced by knowledge workers and by those who have more customer interface. Historically clerical employees were more likely to have fixed working hours, which contributed to higher morning and evening traffic peaks.

In recent years increased globalization has led to a change in working patterns. Business is now conducted across international time zones and working hours have become more flexible to encompass this. The traditional 9–5 working day has given way to a 24-hour working environment and as a result the demand for lift services has also changed.

5. TOWARDS NEW DESIGN CRITERIA

The highest demand is seen in buildings with small populations. This is because a low number of people represent a high percent of the building population. These peaks are not sustained, so are manageable without designing specifically for them.

Figure 11 shows the range of total passenger demand measured in a major office with an observed population in excess of 1000 people. Total demand includes incoming, outgoing and interfloor traffic.

In most modern office buildings, there is a greater demand at lunchtime than the morning. However, both morning and lunch periods need to be considered as part of the design process. In the morning, the lifts 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-lifted). However, at lunchtime, the cars stop more often, leading to longer waiting times.

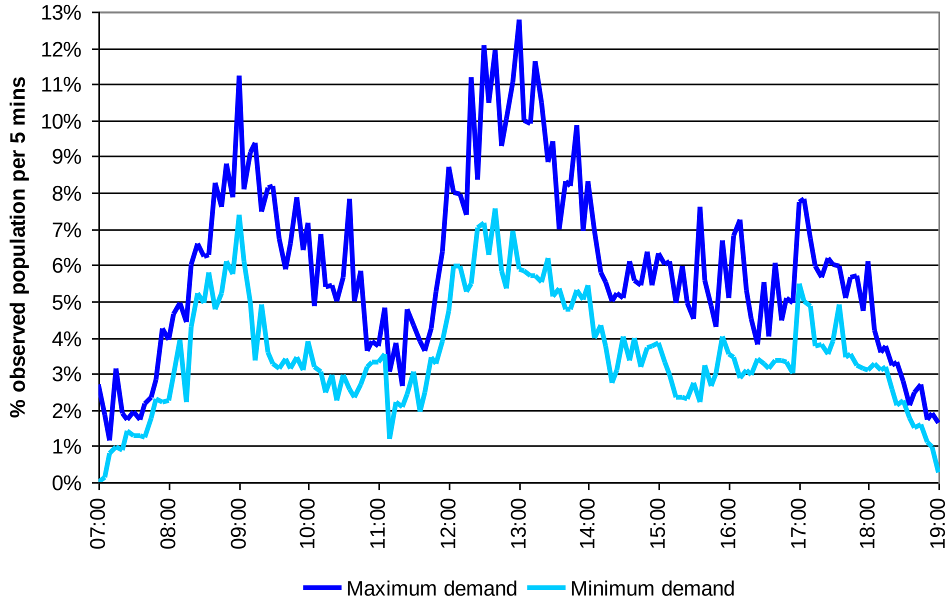

Figure 11 Passenger demand range for major office buildings

Passenger demand templates based on this research have been developed for new editions of industry guidance documents due for publication in 2011.[1,2] The templates can be applied to simulation programs to evaluate anticipated performance of lift systems. These templates can also be used to evaluate improvements to dispatching algorithms in simulation.

6. CONCLUSIONS

The pattern of passenger demand measured in our surveys closely resembles the traffic results presented by Siikonen. Traffic in modern office buildings is markedly different from those of the past.

While peak traffic periods still exist today, the amplitude of those peaks is not as great and the duration is longer. Total passenger demand is normally (but not always) greater at lunchtime than it is during the morning up-peak. Major down-peaks are rarely seen.

The passenger demand in buildings shows consistency day to day; individual office buildings have a unique and repeatable signature. This knowledge is valuable in the design of lift dispatchers, and for traffic analysis. Lift control systems should be designed to detect and manage the new patterns of passenger demand in modern buildings.

Selection of new lift systems should be based on modern as opposed to historical measurements of passenger demand. In many instances, this will result in smaller, or in selected cases, fewer lifts and thus more energy efficient lifts being specified. Modern form of lift group control, for example, destination control, can also contribute to lesser requirements.

Analysis based on realistic traffic estimates is the best way to predict the quality of service. Design recommendations based on this research will be included in future industry design documentation. The application of automatic logging to gather large amounts of data will help the industry to assess hypotheses about passenger behaviour and lift system operation.

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