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Traffic Patterns in Hotels and Residential Buildings

Marja-Liisa Siikonen

KONE Corporation, Keilasatama 3, 01250 Espoo, Finland, e-mail: marja-liisa.siikonen@kone.com

INTRODUCTION

Traffic patterns in office buildings are quite well-known – there is an up-peak in the morning, a mixed lunch-hour traffic peak and a down-peak in the evening. Lift planning and selection criteria for offices are based on the morning up-peak and lunch-hour traffic. The traffic patterns of hotels and residential buildings, however, have not been discussed much publicly. One reason is that in hotels and residential buildings traffic is expected to depend on cultural and regional issues more than in offices. At the moment, global hotel chains have their own standards for planning lifts, and these standards are mostly based on two-way traffic. This paper gathers together the existing lift-planning practices and selection criteria for hotels and residential buildings. In addition, measured daily traffic profiles of hotels and residential buildings are introduced.

CURRENT LIFT-PLANNING PRACTICES

Selection of hotel lifts. Major hotel chains such as Accor, Hilton, Hyatt, Marriott, Four Seasons, Starwood, Ritz-Carlton, and Radisson have their own standards for vertical transportation. The type of the hotel affects the population estimation. For example, an urban city hotel has less people per room than a holiday resort hotel. Strakosch [1] has already introduced population criteria for hotels and motels suggesting the density of 1.5–1.9 guests per room. These are quite in line with the hotel chain design criteria. In some guidelines, the maximum number of guests is counted from the number of beds or room keys. The hotel guidelines are summarized in Table 1. Modern guidelines give their criteria according to the hotel star rating, and use passenger Waiting Times (WT) and Times to Destination (TTD) instead of lift Interval.

For low-rise hotels with less than 10 floors, the guidelines give rules of thumb or tables to select the number and the speed of guest lifts. The number of lifts is roughly defined by the number of rooms where one additional lift is required for every additional 100 guest rooms. CIBSE, however, recommends one lift per 100 hotel guests [2]. In four to five-star hotels, the rated load for passenger lifts is commonly 1 600kg with 1 100 mm wide centre-opening doors, and the load of 1 275kg is accepted as a minimum. In low-rise hotels of fewer than 10 floors, smaller loads, e.g. 800–1 000kg can be used for guest lifts.

According to the hotel standards, the lift speed is defined by the number of floors and population. In Fig. 1, the speed values of the guidelines are shown by data points. An equation that fits well to the guideline values is

$$v = (s-1)*H/T. \quad (1)$$

where the speed is denoted by *v*, with the minimum value of 1m/s. The speed depends on the number of the floors, *s*, and the floor height, *H* (here 3m). The constant, *T*, corresponds to the nominal travel time, with the value of 20s. The speed curve of Eq. 1 is also shown in Fig. 1.

Table 1. Design guidelines for hotel guest lifts according to hotel star rating.

Hotel rating	HC	WT	TTD	Density	Rated car load
	(%/5 min)	(s)	(s)	(guests/room)	kg
★★★★★	12-16	20-40	70-90	1.7-1.8	1 600
★★★★	12-14	30-45	70-90	1.5-1.8	1 600
★★★	12	30-45	90-120[1]	1.3-2	1 275

For luxury or tall hotels, the selection of guest lifts is based on two-way traffic analysis. Collective control is recommended, but also Destination Control is mentioned in the latest guidelines. Handling Capacity (HC) should exceed 12% in five minutes. In resort hotels and motels, Handling Capacity of 10% in five minutes is accepted. In a five-star hotel, average waiting times should stay below 30s, when in hotels with lower ratings even 45s waiting times are accepted. The given values for Times to Destination are quite short, the maximum being 90s. Normally, a 40% car load factor is assumed when guest baggage is carried in the same lift, although up to a 55% value is allowed. Service is usually handled with separate lifts with, e.g., 1800kg load. The number of service lifts is roughly 50-75% of the number of guest lifts. For transporting large or heavy items, freight lifts up to 3 000kg with speeds of 0.3 –0.5m/s are used. If there are parking floors in the hotel, for security reasons it is good to have distinct elevators which serve the traffic between the parking floors and the hotel lobby.

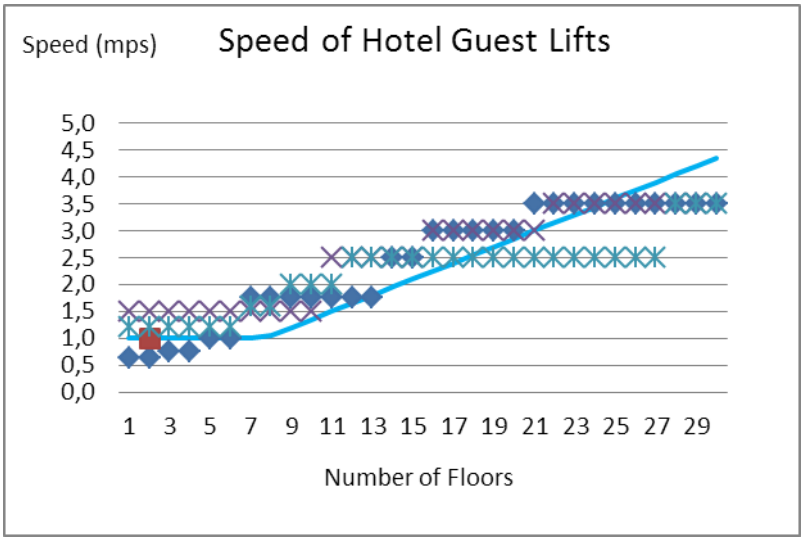

Figure 1. Selection of hotel guest lift speed according to the number of floors (data points refer to the values of different hotel chains, and the solid curve is plotted from Eq. 1).

Lift selection for residential buildings. In selecting lifts for low rise apartment buildings, the best practice is to follow local standards. Lifts are mainly needed for the residents, and parking floors can be served directly by the same lifts. In tall buildings, where there are frequent moves in and out, an additional service lift is needed. In high-rise serviced apartments with maids, more than one service lift may be needed. The selection criteria approach hotel criteria. The rated loads of residential lifts vary from 320 to 1000kg. The rated speed can be lower than in hotels with the nominal travel time of 30s [3]. In Equation (1), the value of 30 instead of 20 can be used for the constant *T*.

The population estimation is based on the number of bedrooms, and depends much on the culture. Barney suggests 1.5–2 persons in the first bedroom, and 0.5-2 persons for further bedrooms [3]. Strakosch suggests 20m^2 of net area per person when the layout and utilization of residential floor is unknown, or 1.5-2 persons per bedroom [1].

Table 2. Practices with residential passenger lifts.

Residential	HC	WT range	TTD range	Density	Car load
	(%/5 min)	(s)	(s)	(guests/room)	kg
Serviced Apartments	10-12[1]	30-45	90-120	1.8/first bedroom + 1.4*no of additional bedrooms	1150-2000
High-rise (>10 floors)	7.5-10[1]	30-60	90-150[1]	1.8/first bedroom + 1.2*no of additional bedrooms	1000-1 600
Low-rise (< 10 floors)	5-7.5	35-70	90-120	2/first bedroom + 1*no of additional bedrooms	320-1 275

Handling Capacity requirements in residential buildings currently vary between 5–9% in five minutes. Thus, lift capacity or the number of lifts is smaller than in hotels. With fewer lifts, Interval and passenger Waiting Times become longer. The Waiting Time requirement varies between 30 and 60s, and Time to Destination is between 90 and 150s due to the lower lift speeds.

MEASURED TRAFFIC PATTERNS

Measurement methods. The people flow in passengers per 5 minutes was measured in four hotels and four residential buildings in six countries: Finland (FI), France (FR), Egypt (EG), Hong Kong (HK), Singapore (SI), and UAE (DU). The measured hotels had four to five-star ratings, and were from 10 to 55 floors tall while the measured residential buildings had 15 to 50 floors. In all the lift groups, a conventional full collective control system was used. The population in the hotels was estimated from the number of rooms with 1.7 person occupancy per room, and from the number of available room keys. In apartment buildings, the population was calculated from the rooms using the rules of Table 1. By dividing the measured arrival rates by the population, the relative arrivals rates in % per 5 minutes were obtained. The number of people using the lifts was measured and analyzed in three different ways:

1) The traffic was measured with a pen and paper method, with an observer sitting in the lift lobby and marking down the number of incoming and outgoing passengers. The times of each entry were written down with one minute accuracy. People in residential buildings in Espoo, Finland and Singapore were counted from 7am to 7pm, and from 8am to 8pm for the hotel buildings in Singapore. All the measured days were normal weekdays. The population in the apartment building in Finland was about 100 persons and in Singapore about 400 persons. The population of the hotel in Singapore was about 700 persons.
2) Lift Traffic Analyzer (LTA) was connected to the control system to measure certain signals: lift starts, landing calls, door states, and photocell signal cuts from the car door openings [4]. The number of people using the lifts on all floors was analyzed from the photocell signals for the whole day. The photocell signal, however, does not provide information of whether a passenger enters or exits the car. With the LTA, the traffic of a hotel in Helsinki, Finland, and a residential building in Marseille, France was measured. The hotel had 170 guests and the apartment building 500 inhabitants.
3) The most comprehensive people flow estimation was obtained from the group control which can measure the number of entering and exiting passengers, and also the inter-floor traffic on upper floors. The people were counted by the TMS9000 control system [5,6] for the whole day in Cairo, Egypt, in Dubai, UAE, and in Hong Kong. The estimated population in the hotel in Cairo was 1 240 persons, and in Dubai 490 persons. The residential building in Hong Kong had 760 inhabitants.

Measurement results. The traffic is mostly two-way in both building types, but traffic intensity is higher in hotels. The relative arrival rates of the hotels are shown in Fig. 2. There are two traffic

peaks: one is in the morning when people have breakfast and check out, and the other is in the evening when people check in and have dinner. The widths and the heights of the peaks as well as the portions of incoming, inter-floor and outgoing components vary according to the building layout and the culture. The inter-floor traffic is caused by the common floors including, e.g., gyms, restaurants, and business centers. In the measured hotels, the maximum arrival rate was 9.5% of the population in five minutes.

Among the four residential buildings, the maximum traffic peak was 5.7% in five minutes as can be seen in Fig. 3. In the residential buildings, there is a down-peak in the morning, somewhat more incoming traffic in the evening, and only little inter-floor traffic during the day.

For planning purposes, the individual building measurements were combined into average and worst-case profiles. For the average profile, the average of all arrival rates were calculated, and, for the worst-case profile, the maximum arrival rate of the four measurements for each interval was selected. In Fig. 4 and Fig. 5, the average profile divided in traffic components, and the worst-case profiles with dashed lines are shown. Numerical values of the resulting profiles are shown in Appendix 1. The portions of the incoming, inter-floor and outgoing components are averages of the four building measurements, and are given in per cent of the arrival rate.

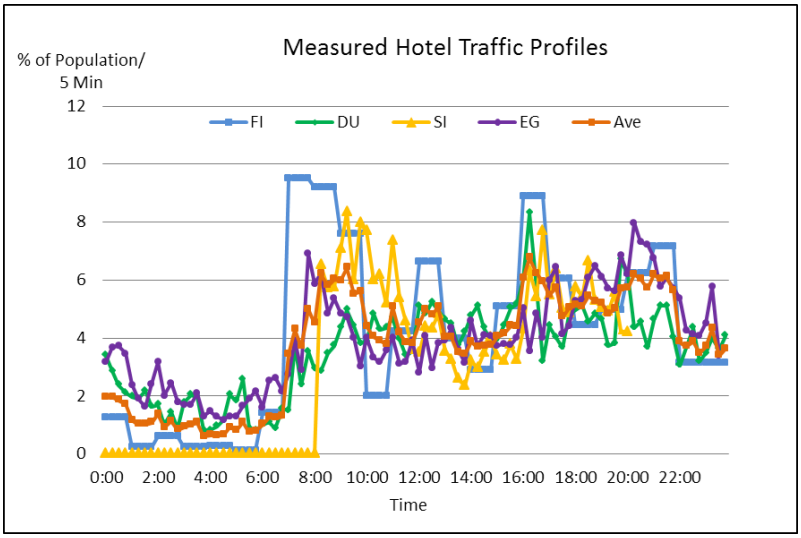

Figure 2. Four measured and the average daily traffic profiles of hotels.

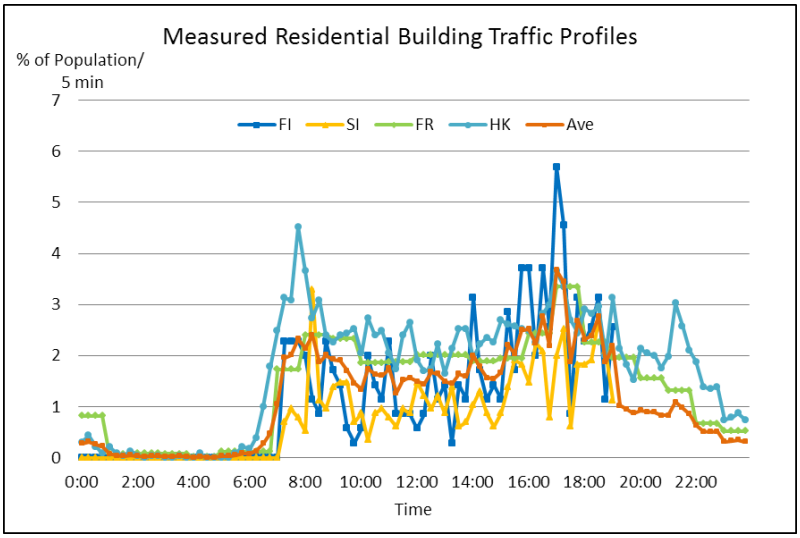

Figure 3. Four measured and the average daily traffic profiles of residential buildings.

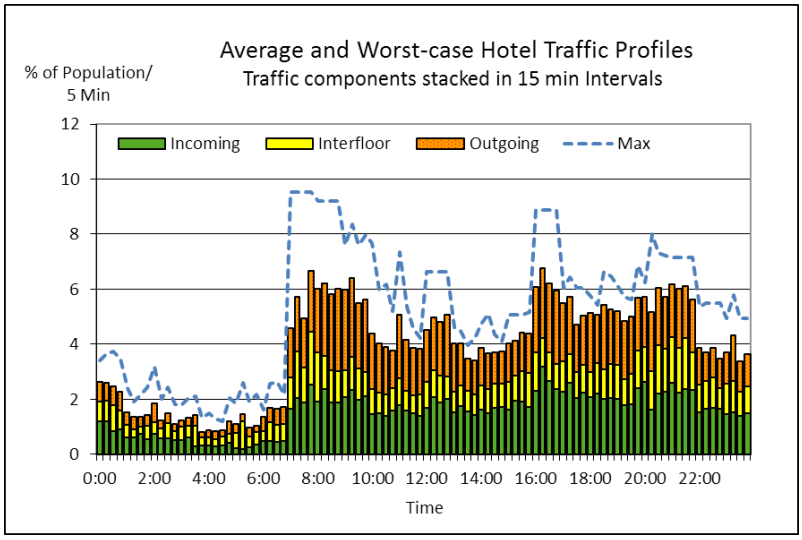

Figure 4. Average daily traffic divided in components, and the worst-case profile (dashed line) of hotels.

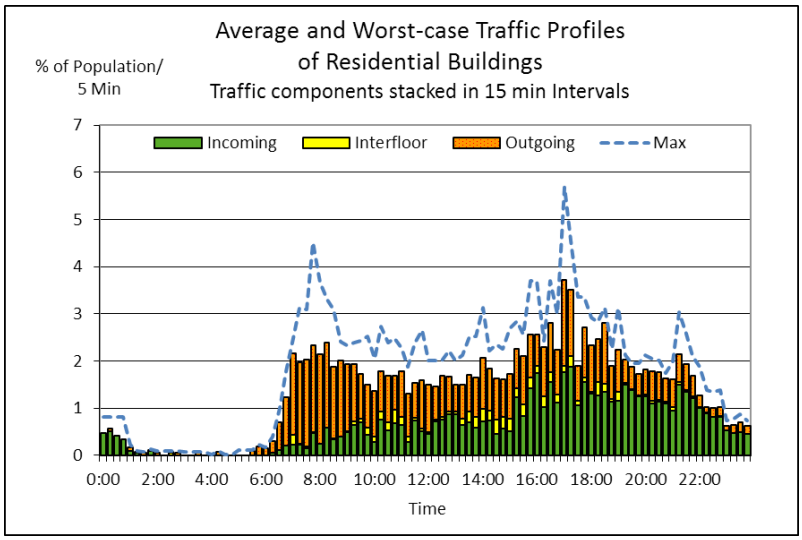

Figure 5. Average daily traffic divided in components, and the worst-case profile (dashed line) of residential buildings.

DISCUSSION

In this paper, the planning standards of passenger lifts in hotels and residential buildings were discussed. If the planning criteria are compared with the measured traffic profiles in the buildings, the assumption of using two-way traffic in the analysis seems to have a firm basis.

The measured hotel profiles as well as the residential profiles resemble each other although the measurements were made in different parts of the world. Measured traffic was heavier in the hotels compared to the apartment buildings. In hotels the traffic is mostly two-way, but also a little inter-floor traffic. Arrival rates are higher in the morning and in the afternoon during check-in. In residential buildings the traffic is two-way. There is, however, more down traffic in the morning, and in the evening more incoming traffic.

The average profile of the four measurements in each building type was calculated. Averaging flattens the peaks since they occur at slightly different times. That is why the worst-case profile with maximum intensities was formed. The measured maximum peak in the four to five-star hotels was 9.5% in five minutes, which is below the planning standard of 12% in five minutes. The hotels probably were not fully booked during the measurement, and the population was thus below the planned population. The maximum peak in the measured residential buildings was 5.7% in five minutes that is in the range of the planning criteria of 5–7% in five minutes.

If the actual population differs from the planned population, the relative arrival rates of Appendix 1 can be rescaled. As an example, if the actual population is 80% of the planned, the relative arrival rates of the appendix can be divided by 0.8. The arrival rates of each traffic component are obtained by multiplying the relative arrival rate by the proportions of the traffic components given in the table.

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Appendix 1. Daily traffic patterns of hotel and residential buildings

	Hotel					Residential				
Time	Traffic components			Arrival rate		Traffic components			Arrival rate	
	Incoming	Inter-floor	Outgoing	Average	Worst-case	Incoming	Inter-floor	Outgoing	Average	Worst-case
[Hh:mm]	[%]	[%]	[%]	[% / 5 min]	[% / 5 min]	[%]	[%]	[%]	[% / 5 min]	[% / 5 min]
0:00	44	26	30	2.0	3.4	100	0	0	0.3	0.8
0:15	44	27	29	2.0	3.7	87	1	12	0.3	0.8
0:30	34	34	32	1.8	3.7	100	0	0	0.3	0.8
0:45	44	28	28	1.7	3.5	100	0	0	0.2	0.8
1:00	42	27	31	1.2	2.4	54	1	45	0.1	0.2
1:15	44	22	34	1.0	1.9	79	1	20	0.0	0.1
1:30	50	19	31	1.0	2.2	66	1	33	0.0	0.1
1:45	39	30	31	1.1	2.4	85	1	14	0.0	0.1
2:00	41	23	36	1.4	3.2	61	1	38	0.0	0.1
2:15	45	28	27	0.9	2.0	0	0	100	0.0	0.1
2:30	39	35	26	1.1	2.4	0	59	41	0.0	0.1
2:45	45	26	29	0.8	1.8	61	1	38	0.0	0.1
3:00	41	37	22	0.9	1.8	0	0	100	0.0	0.1
3:15	45	29	26	1.0	2.0	0	0	100	0.0	0.1
3:30	22	48	30	1.1	2.1	63	1	36	0.0	0.1
3:45	40	32	28	0.6	1.3	0	0	100	0.0	0.1
4:00	36	34	30	0.6	1.5	0	0	100	0.0	0.0
4:15	35	28	37	0.6	1.3	46	1	53	0.0	0.1
4:30	36	36	28	0.7	1.2	0	0	100	0.0	0.0
4:45	34	27	39	0.9	2.0	0	0	100	0.0	0.0
5:00	21	50	29	0.8	1.8	0	0	100	0.0	0.1
5:15	14	66	20	1.1	2.6	0	0	100	0.0	0.1
5:30	27	39	34	0.7	1.9	0	0	100	0.1	0.1
5:45	32	43	25	0.8	2.2	0	0	100	0.1	0.2
6:00	35	25	40	1.0	1.6	0	0	100	0.1	0.2
6:15	29	38	33	1.3	2.6	20	1	79	0.1	0.4
6:30	29	35	36	1.2	2.6	16	1	83	0.3	1.0
6:45	29	34	37	1.3	2.2	16	1	83	0.5	1.8
7:00	36	24	40	3.4	9.5	12	7	81	1.1	2.5
7:15	35	30	35	4.3	9.5	10	3	87	2.0	3.1
7:30	38	25	37	3.7	9.5	7	3	90	2.0	3.1
7:45	38	28	34	5.0	9.5	20	1	79	2.3	4.5
8:00	32	30	38	4.5	9.2	10	2	88	2.1	3.7
8:15	36	24	40	6.2	9.2	24	1	75	2.4	3.3
8:30	30	25	45	5.8	9.2	17	3	80	1.9	3.1
8:45	29	24	47	6.0	9.2	19	1	80	2.0	2.4
9:00	32	22	46	6.0	7.6	25	2	73	1.9	2.3
9:15	34	24	42	6.4	8.3	33	5	62	1.9	2.4
9:30	34	25	41	5.5	7.6	39	6	55	1.7	2.4
9:45	35	22	43	5.6	8.0	29	11	60	1.5	2.5
10:00	30	28	42	4.4	7.7	20	10	70	1.3	2.0
10:15	34	25	41	4.0	6.0	42	10	48	1.7	2.7
10:30	33	27	40	3.9	6.2	31	11	58	1.6	2.4
10:45	39	27	34	3.8	5.2	40	18	42	1.6	2.5
11:00	32	26	42	5.1	7.4	36	10	54	1.7	2.3
11:15	35	24	41	4.2	5.4	22	9	69	1.3	1.9

11:30	36	23	41	3.8	4.6	48	5	47	1.5	2.4
11:45	35	24	41	3.8	4.2	31	6	63	1.6	2.7
12:00	35	25	40	4.5	6.6	30	3	67	1.5	2.0
12:15	39	24	37	5.0	6.6	49	3	48	1.4	2.0
12:30	37	25	38	4.8	6.6	44	5	51	1.7	2.0
12:45	37	21	42	5.1	6.6	52	4	44	1.6	2.2
13:00	36	23	41	4.0	4.6	57	5	38	1.5	2.0
13:15	41	24	35	4.0	4.5	42	11	47	1.5	2.1
13:30	42	26	32	3.5	4.0	41	14	45	1.6	2.5
13:45	40	25	35	3.4	4.2	35	15	50	1.6	2.5
14:00	40	27	33	3.9	4.8	34	14	52	2.0	3.1
14:15	39	28	33	3.7	5.1	39	13	48	1.8	2.2
14:30	43	28	29	3.7	4.4	27	20	53	1.6	2.3
14:45	43	28	29	3.7	4.1	35	17	48	1.5	2.3
15:00	38	29	33	4.0	5.1	29	16	55	1.7	2.7
15:15	45	26	29	4.1	5.1	54	10	36	2.2	2.8
15:30	41	29	30	4.4	5.1	39	13	48	2.0	2.6
15:45	37	32	31	4.4	5.2	55	10	35	2.5	3.7
16:00	36	27	37	6.1	8.9	68	7	25	2.5	3.7
16:15	45	20	35	6.8	8.9	44	11	45	2.2	2.4
16:30	40	22	38	6.2	8.9	55	8	37	2.8	3.7
16:45	37	22	41	5.9	8.9	50	8	42	2.2	3.0
17:00	39	25	36	5.5	6.1	47	5	48	3.7	5.7
17:15	42	24	34	5.7	6.5	53	7	40	3.4	4.6
17:30	40	26	34	4.7	6.1	55	6	39	1.9	3.4
17:45	42	25	33	5.0	6.1	57	4	39	2.7	3.4
18:00	38	23	39	5.1	5.8	55	3	42	2.3	2.9
18:15	41	26	33	5.1	5.4	51	12	37	2.4	2.8
18:30	35	25	40	5.4	6.6	47	8	45	2.8	3.1
18:45	36	28	36	5.3	6.5	60	4	36	1.9	2.3
19:00	36	29	35	5.2	6.1	51	9	40	2.2	3.1
19:15	35	24	41	4.8	5.7	74	2	24	1.0	2.1
19:30	34	27	39	5.0	5.6	73	2	25	0.9	2.0
19:45	40	28	32	5.7	6.9	71	3	26	0.9	2.0
20:00	44	26	30	5.7	6.2	68	3	29	0.9	2.1
20:15	36	28	36	6.2	8.0	62	3	35	0.9	2.0
20:30	38	26	36	6.0	7.3	64	3	33	0.9	2.0
20:45	40	25	35	5.7	7.2	67	3	30	0.8	1.8
21:00	43	25	32	6.2	7.2	58	5	37	0.8	2.0
21:15	39	26	35	6.0	7.2	69	4	27	1.1	3.0
21:30	41	27	32	6.1	7.2	69	3	28	1.0	2.6
21:45	42	24	34	5.6	7.2	71	3	26	0.9	2.1
22:00	42	24	34	3.9	5.4	79	2	19	0.6	1.9
22:15	45	25	30	3.7	5.5	87	2	11	0.5	1.4
22:30	44	26	30	3.9	5.5	79	1	20	0.5	1.3
22:45	47	21	32	3.5	5.5	79	4	17	0.5	1.4
23:00	39	27	34	3.7	4.9	84	1	15	0.3	0.7
23:15	37	24	39	4.3	5.8	72	1	27	0.3	0.8
23:30	40	24	36	3.4	4.9	70	1	29	0.3	0.9
23:45	40	25	35	3.6	4.9	71	1	28	0.3	0.7