# Improvement of Single Elevator Operation by Using Prior Stand by Control

Kenichi Yamashita[1)], Atsuya Fujino[1)], Toshimitsu Tobita[1)], Ryou Okabe[2)] and Kenji Kawano[3)]

*Hitachi, Ltd. Elevators & Escalators[1)]: Hitachinaka, Ibaraki, Japan*

*Hitachi Mito Engineering Co., Ltd.[2)]: Hitachinaka, Ibaraki, Japan*

*Hitachi Building Systems Co., Ltd.[3)]: Adachi, Tokyo, Japan*

## ABSTRACT

This paper introduces an operation control method with a learning function for single elevators. The method learns passengers' "punctual" elevator use, e.g. a regular time to leave for work in the morning in a residential building, and serves an elevator prior to the learned floor which stands by for each learned passenger. Computer simulation shows it can serve an elevator prior to the learned floor and the passenger can board the elevator immediately when arriving passengers number is 2 persons or less per 5 minutes. Measured operation data at an actual residential building show waiting time was about 10% shorter than with the conventional method.

## 1. Introduction

Studies on elevator operation control have been mainly done for several elevators as a group and a number of control methods have been put to practical use.[1] To operate 1 or 2 elevators efficiently, on the other hand, Collective Control and Duplex Collective Control are in use. With Collective Control, hall calls in the direction in which the car is traveling, are responded to sequentially and when all calls in that direction are served, calls in the opposite direction are responded to. Duplex Collective Control supposes cars will move as a ring, and calls are responded to by whichever car can serve the call faster. [2] In addition, stand by operation at the starting floor and dispersion stand by operation in the system are used to improve a service. Various investigations are also being done from the viewpoint of operations research, but few things have been put to practical use as compared to the many methods of group control for several elevators.

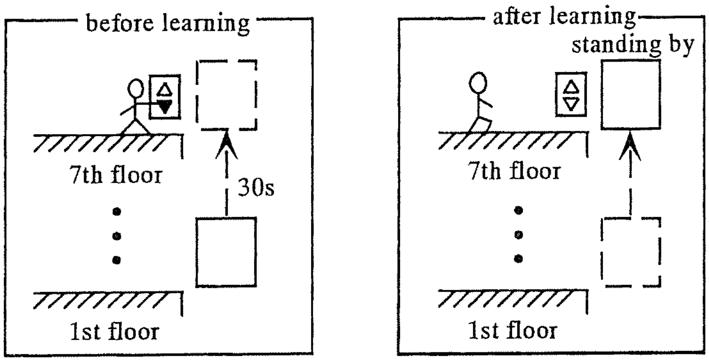
The numbers of residential buildings with elevators are increasing in Japan, so that it is necessary to improve the service for their users. In this paper, we propose a new control method which makes an elevator stand by after learning the regular use time of a passenger and forecasting it before the passenger arrives at the elevator hall. The method and its applicable range are examined by simulation and sample results of the method in an actual residential building are introduced.

## 2. Prior Stand By Control

Many passengers use an elevator at a regular time to leave for work in the morning in a residential building. In this paper, we propose “prior stand by control” which makes an elevator stand by after learning the regular use time of a passenger and forecasting it before the passenger arrives at the elevator hall.

Fig. 1 outlines the operation of prior stand by control. For example, there is a passenger who uses an elevator from the 7th floor of the residential building every day at the same time. Supposing that the elevator is always on the 1st floor, the passenger is kept waiting for 30 seconds every day. Waiting time can be shortened very much by making an elevator stand by on the use floor in advance before the passenger appears in the elevator hall.

When forecast of the passenger's arrival time is successful, prior stand by control lets the passenger ride on the elevator immediately. Even when the forecast fails, waiting time is equal to or less than that of the conventional control (the elevator will stand by at the starting floor or the elevator will remain at the last served floor). The waiting time is shortened by the degree to which the forecast is successful.




Waiting time is 30 seconds. Waiting time is 0 second.

*Fig. 1 Prior stand by control*

The system configuration for prior stand by control is shown in Fig. 2. Parts added to the conventional control system are shaded. The learning part learns the time and floor when a passenger used an elevator, based on information from the hall button and the clock. The forecast part detects the passenger who uses the elevator every day at the same time from the learning result. When the passenger would usually appear in the elevator hall, the forecast part sends an order making the elevator stand by, to the operation part. When an actual call is made while driving in stand by control, the stand by operation is canceled and priority is given to the actual call. The maintenance device sets the clock inside the control device on-line at the correct time.

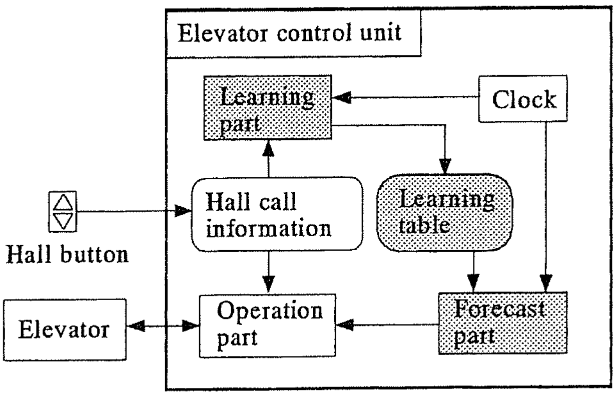



*Fig. 2 System configuration*

## 3. Learning Method and Forecast Method

### 3.1 Learning method

In prior stand by control, an elevator is made to stand by for a passenger who has used the elevator from the same floor at the same time on 3 days from among the past 7 days. Therefore, we use a learning method which grasps the use conditions of a constant period easily.

The moving average method is given in equation (1) where D(k) shows the traffic pattern data of day k, P(k) shows the learning result of day k, and n shows the number of learning days. The moving average method calculates the average of the traffic pattern data during n days and calculates the passenger arrival probability from that average. Learning with this method makes it easy to design the program which makes an elevator stand by on the floor which a passenger used regularly. Therefore, we decided to use the moving average method for learning.[3]

$$P(k) = \frac{D(k-1) + D(k-2) + \cdots + D(k-n)}{n} \tag{1}$$

### 3.2 Forecast method

Usually, learning or forecasting is done in a fixed time interval (for example, five minutes). However, it is difficult to set the time interval to the appropriate length.

Fig. 3 shows the relationship between the time interval of learning and passenger arrival probability. Fig. 3(a) shows a case in which the time interval is 1 minute when passenger A arrived on the 3rd floor, and Fig. 3(b) shows a case in which the time interval is 10 minutes when passenger B arrived on the 4th floor and passenger C arrived on the 5th floor.

We assume the condition that the elevator is made to stand by, when passenger arrival probability is more than 60%. Then, the elevator should be made to stand by for the case of Fig. 3(a) because the passenger arrival probability from 7:28 to 7:31 is 80%. But the elevator does not stand by because individual probabilities are less than 30% in the interval of 1 minute. Although the elevator should be made to stand by for each passenger for the case of Fig. 3(b), judgment can not be made for which passenger arrives first because it exists in the same interval. Therefore, it is difficult to decide the learning interval as an appropriate length uniquely.

When occupants of the residential building change, the traffic pattern changes, too. Then, the learning interval should be able to change corresponding to the conditions.

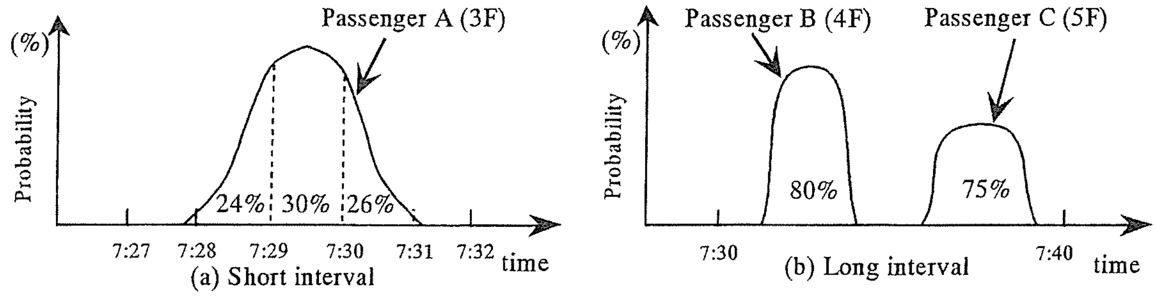



*Fig. 3 Relationship between learning interval and passenger arrival probability*

To solve the problem, the learning or forecasting interval must be changed corresponding to the traffic pattern. There are 2 ways to change the time interval. One changes the learning interval. The other changes the forecast interval. Because the learning part processes data every day, the calculation becomes complicated when the interval is changed daily. In case of forecasting, only the learning data are referred to by the forecast part, so the forecast process never becomes complicated by changing the forecast interval. Therefore, we choose a fixed learning interval, and a changeable forecast interval. We call our approach the forecast interval changing method.

Fig. 4 shows how the forecast floor and time are calculated from the learning table. The passenger arrival probability of each floor is recorded in the learning table at the fixed interval (1 minute). Each row in a column of the learning table is added. In the 3rd column, the probability of the 3rd floor becomes 0.7 when rows until 7:23 are added. The forecast floor is decided as the 3rd floor because the probability is beyond the pre-determined threshold (0.6 here). And 7:20-7:23 is taken as the time when the elevator is made to stand by on the 3rd floor.

| | 1st | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|
| 7:20-7:21 | 0 | 0 | 0.2 | 0.3 | 0.1 |
| 7:21-7:22 | 0 | 0 | 0.3 | 0.1 | 0.1 |
| 7:22-7:23 | 0 | 0 | 0.2 | 0.1 | 0.2 |
| 7:23-7:24 | 0 | 0 | 0 | 0 | 0.1 |
| 7:24-7:25 | 0 | 0 | 0.1 | 0.2 | 0.1 |

Learning table

→ Forecast floor: 3rd floor

Forecast time: 7:20-7:23

Forecast result

*Fig. 4 Forecast method*

## 4. Problems of Uneven Use Time and Traffic Demand

When the application range of the prior stand by control is examined, unevenness of use time and traffic are important.

### 4.1 Unevenness of use time

We suppose that passengers A and B use an elevator at the times shown in Table 1. Average use time of both passengers is 6:31. Passenger A uses the elevator within 3 minutes of that time. But unevenness of use time is big for passenger B. In such a situation, it is easy to forecast time for passenger A to use the elevator, but not for passenger B. Therefore, unevenness of elevator use time should be small.

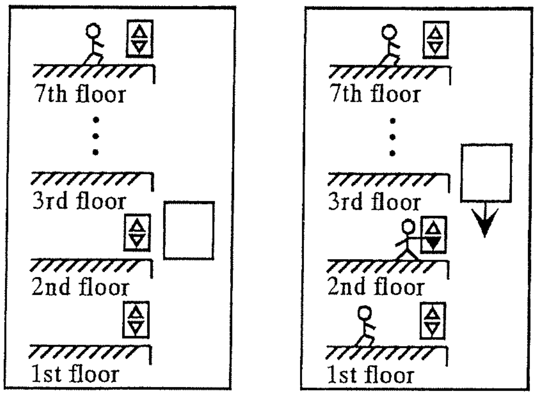
*Table 1 Unevenness of elevator use time*

| | 1st day | 2nd day | 3rd day | 4th day | 5th day | Average | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Passenger A | 6:30 | 6:32 | 6:27 | 6:34 | 6:32 | 6:31 | 3 min |
| Passenger B | 6:30 | 7:10 | 6:05 | 6:15 | 6:35 | 6:31 | 25 min |

### 4.2 Traffic demand

Fig. 5 shows the difference in passenger appearance for 2 conditions of traffic demand. Fig. 5(a) shows the case of small traffic, and Fig. 5(b) shows that of large traffic. When a hall call does not occur from other floors while an elevator is being moved to the purpose floor, the elevator can stand by on the passenger's use floor in advance. In the case of large traffic, many passengers want to use the elevator at the same time, and the order of their appearance is different every day (for example, 1st-2nd-7th or 2nd-7th-1st). In addition there is little correlation for each passenger's appearance. Therefore, it is difficult to forecast the floor for standing by. In the case of large traffic, when passengers appear without a break, the elevator can not stand by in advance as a matter of course because there is not enough time to allow the elevator to stand by.

Under these circumstances, to make an elevator stand by on the passenger's use floor in advance, it is necessary that both traffic demand and unevenness of passenger use time are small. Results showing application range of the control from a simulation are shown next.




(a) Small traffic demand (b) Large traffic demand

*Fig. 5 Passenger arrival probability distribution depending on traffic demand*

## 5. Simulation Results

We simulated prior stand by control in a residential building using the conditions shown in Table 2. The floors at which passengers appeared in simulation were decided by random numbers. The passengers appeared on the 2nd to 6th floors and they went to the 1st floor. This traffic pattern was made assuming morning. Morning in the residential building is a typical example in which each passenger uses the elevator at the same time, and it is suitable for confirming the effect of prior stand by control.

*Table 2 Simulation specification*

| Item | Specification |
|---|---|
| Number of floors | 6 |
| Traffic quantity | 0.5, 1, 2, 5, 10<br>[Person/5min] |
| Standard deviation | 1, 5, 10, 20[min] |
| Elevator specification | 1car, 60m/min (1m/s), 9 persons |

Fig. 6 shows the forecast success percentage for each traffic quantity and standard deviation. The ratio that a passenger actually appeared on the floor for which the elevator stood by in advance as a learned result was defined as the forecast success percentage. Equation (2) shows this definition.

$$\text{Forecast success percentage} = \frac{\text{Number of forecast successes}}{\text{Number of times stand by}} \tag{2}$$

For smaller traffic quantity and standard deviation, the forecast success percentage is higher. Even if a standing by floor is decided by random numbers, the forecast succeeds with a probability of 1/6 (16.7%) because the simulation building has 6 floors. When the forecast success percentage is less than 20%, it is the same as a hit by chance. Therefore, the application range of the prior stand by control is that the forecast success percentage is more than 20%. When traffic is 2 persons / 5 minutes and standard deviation is less than 10 minutes, the forecast success percentage is more than 20%. Therefore, the effect of the prior stand by control begins to appear at timing of this traffic. When traffic is more than 5 persons / 5 minutes, no matter how small the standard deviation is, the forecast success percentage is less than 20%. Thus, when traffic is large, the prior stand by control, does not work well.

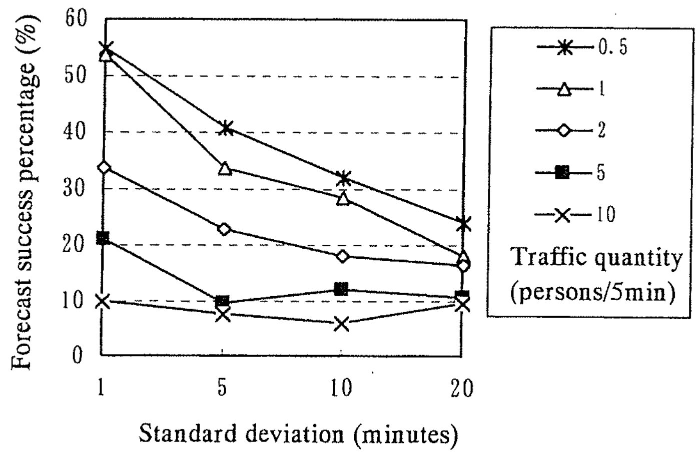



*Fig. 6 Forecast success percentage of each traffic pattern*

Fig. 7 compares waiting time. Standard deviation is 5 minutes, and traffic quantity is 1, 5 and 10 persons / 5 minutes. The conventional method is stand by operation at the starting floor. When the traffic is 1 person / 5 minutes, the waiting time is reduced 34%. When the traffic is 10 persons / 5 minutes, the waiting time is reduced 4%. Thus, as traffic is smaller, the waiting time is smaller. As traffic is smaller, the number of successes of stand by in advance is larger. As a result, the waiting time is reduced. Even when traffic is large, waiting time is smaller in comparison with the conventional control. When traffic is large, the prior stand by control and conventional control provide the same performance level, because the elevator does not have enough time to stand by. Therefore the waiting time of this control never gets longer than the waiting time of the conventional control.

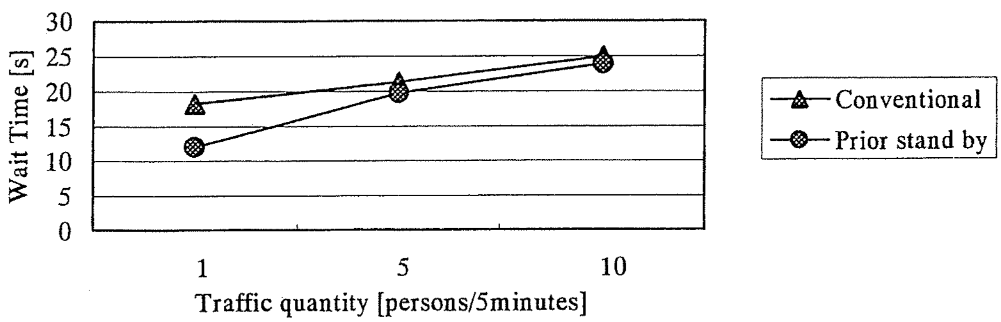



*Fig. 7 Comparison of waiting time*

## 6. Results in an Actual Residential Building

We applied the prior stand by control to an actual residential building. The building specifications are shown in Table 3. There was 1 elevator in the 11-story building. Data were collected for examination from around 6 o'clock to 9 o'clock in the morning. The most punctual passengers are those leaving for work. The data showed the traffic in this time slot was 2 persons / 5 minutes on the average, and standard deviation of unevenness of use time was about 3 minutes. But there was a possibility that there was more unevenness in the passenger's use time, because passenger's use time is the value calculated from the traffic data, and the passenger's follow-up survey is not actually being done.

***Table 3 Residential building specifications***

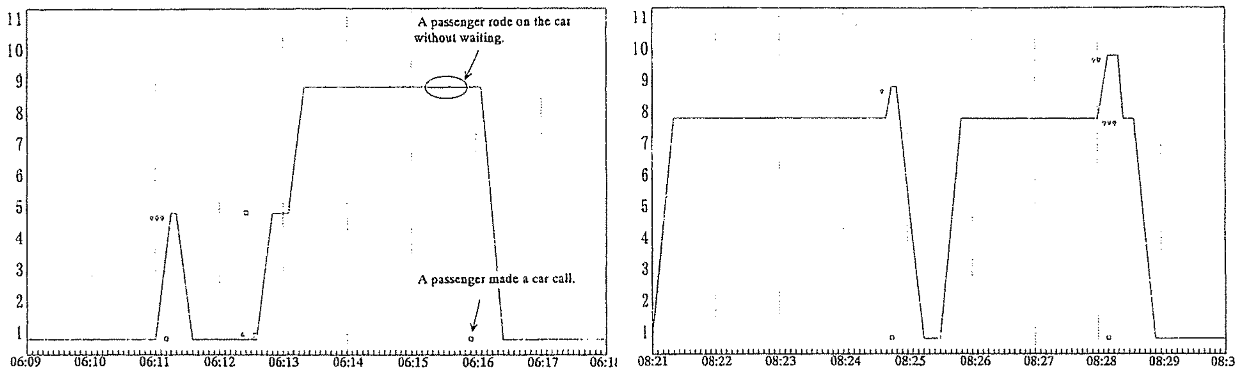
| Item | Specification |
|---|---|
| Floor number | 11 |
| Traffic quantity | About 2 persons/5 min |
| Standard deviation | About 3 min |
| Number of elevators | 1 |
| Elevator speed | 1.5 m/s |
| Capacity of elevator | 9 persons |

Fig. 8 shows the movement of the prior stand by control as an operation diagram. The vertical axis shows floors, and horizontal axis shows time. The line shows the movement of the elevator. Triangles show a hall call and one triangle shows a waiting time of 5 seconds. Squares show car call.

First, Fig. 8(a) shows a successful example of prior stand by control during the time from 6:9 to 6:18. The elevator is moved automatically to the 9th floor at 6:13:5 without a hall call or car call, after the passenger who boarded from the 1st floor at 6:12:20 got off on the 5th floor. This movement is done as prior stand by control. The passenger who arrived at the elevator hall on the 9th floor can board the elevator without waiting because the car call of the 1st floor occurs at 6:16.

One more example is shown in Fig. 8(b) for the time from 8:21 to 8:30. The elevator stands by on the 8th floor at 8:21 as prior stand by control. The elevator stands by on the 8th floor again after a passenger is carried from the 9th floor to the 1st floor at 8:24:40. The prior stand by control is maintained until a passenger comes on the forecasted floor during the time when it was forecast. After that, a passenger arrives at the 10th floor and another passenger arrives at the 8th floor which was forecast at 8:28:5. Therefore, priority is given to the actual call, and the elevator is moved to the 10th floor and then gets to the 8th floor. Even if it has learned properly and stood by, when a sudden hall call occurs from another floor, priority is given to the actual call, and when the passenger's use time is uneven, the passenger can not ride on the standing by elevator. However, for the hall call at the 9th floor at 8:24:40, waiting time becomes short because the elevator stood by near there, and average waiting time becomes short too.

There were 16 cases, when the elevator stood by for regularly arrival passenger without other passengers' use at the time, out of 17 cases. When the use time of passengers is learned, the elevator is made to stand by properly 90% as more of the times. Therefore, there were 3 cases when the passenger boarded the elevator without waiting, and average waiting time is shortened 10% as shown in Table 4.




(a) (b)

*Fig. 8 Prior stand by control examples*

*Table 4 Comparison of waiting time*

| | Waiting time |
|---|---|
| Conventional control | 20.6s |
| Prior stand by control | 18.6s |

## 7. Conclusion

The application range of the prior stand by control was examined with simulations, and the control was applied in an actual residential building and verified. The following conclusions were drawn.

(1) The prior stand by control worked best when traffic quantity was small and unevenness of the traffic pattern was also small. When traffic was less than 2 persons / 5 minutes, the prior stand by control worked best.

(2) When traffic was more than 5 persons / 5 minutes, the prior stand by control had little effect. But the waiting time was never longer than that in a conventional control method for such traffic flow.

(3) The average waiting time was shortened 10% as a result of applying the prior stand by control in the actual residential building.

## REFERENCES

[1] T. Tobita, "Characterized Supervisory Control System for Elevators and Its Support Equipment", T. IEE Japan, Vol. 111-D, No.12, pp1065-1072 (1991)

[2] Inuzuka, The Hitachi Hyoron, Vol. 138-11, pp57-61 (1956)

[3] K. Yamashita, "Study on Development the Efficiency of Elevator Service by Passenger Arrival Forecast", JSME, No.96-51, pp263-266 (1996)