USING ARTIFICIAL INTELLIGENCE TO IMPROVE PASSENGER SERVICE QUALITY

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ABSTRACT

In modern, well-planned high rise buildings with microprocessor controlled elevators call times are already reasonably short. There are, however, service quality indicators other than call times that can be influenced to improve the comfort passengers experience while using an elevator system. The total passenger service quality level, including waiting times, journey times and car load factor can be considered.

Investigations with modern elevator traffic simulators have revealed that passenger waiting times can be much longer than average call times in a building, especially at floors with heavy traffic. This information cannot normally be observed in an elevator system because passenger flow information isn't available.

Simulation studies have proven that a control system using Artificial Intelligence to detect and predict passenger flows and applying this information to call allocation gives superior passenger service compared with older generation controls assigning cars on basis of measured hall call times only.

INTRODUCTION

The new TMS 9000 control system contains an artificial intelligence based 'Traffic Forecaster' software module, which enables the control system to learn, day by day, the fluctuations in the building's traffic pattern. Modern sensor technology is used to measure actual passenger flows. Traffic statistics are saved in the computer's memory. Then, each floor's service need is estimated in advance from the statistical forecasts of passenger traffic. By combining current information on passenger traffic, car load, and calls with the statistical predictions for the particular situation (as measured at the same time during previous days), the service can be balanced between various floors so that individual passenger comfort is ensured. This is done by optimizing passenger waiting times at the landings, shortening ride times in elevators, and balancing car loads.

Passenger traffic recognition

It is important to know the rhythm and dimensions of passenger traffic when making group control decisions. A forecast of passenger traffic gives a more reliable basis for decision-making than a prediction of hall and car calls.

For a complete definition of a building's passenger traffic, the arrival time and floor as well as the destination floor of each passenger are needed. In TMS 9000 control system, four passenger traffic vectors, as shown in Figure 1, are measured at each floor during an elevator stop, providing sufficient information for a practical reconstruction of the traffic pattern.

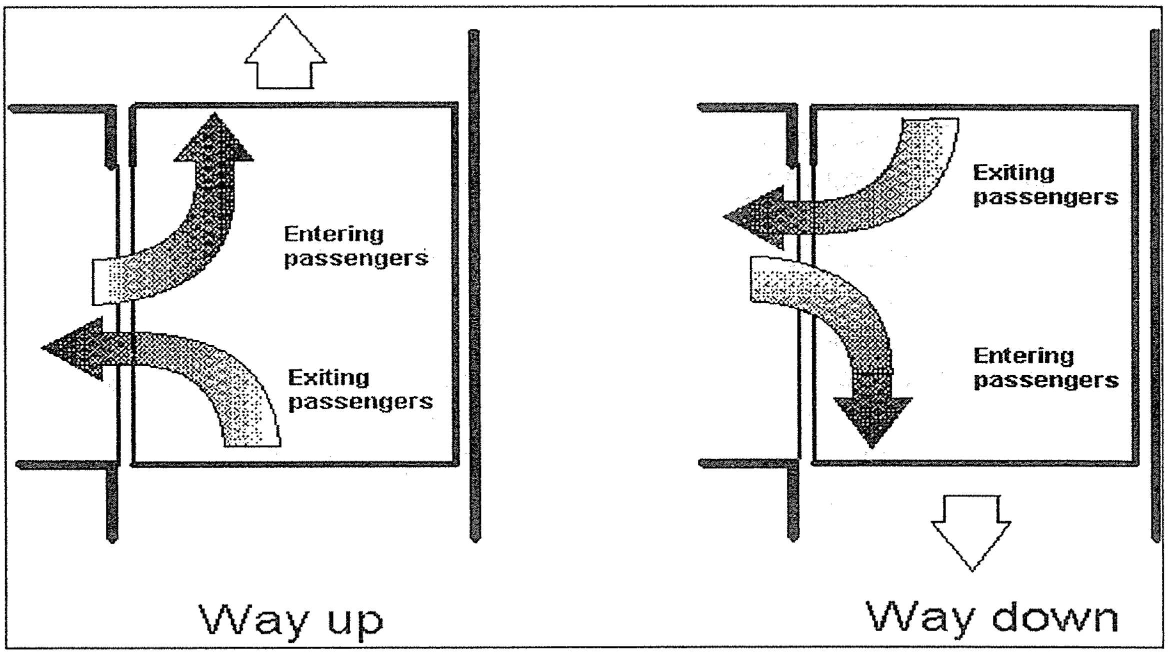

Figure 1. The four possible directions of a passenger entering or exiting an elevator.

The number of passenger transfers at each floor is derived from the car load changes, with complementary input from photocell signals. The car load signals are continuously measured during an elevator stop, converted into digital form, and filtered using the Median Filtering method (patent pending). The number of passenger transfers in and out of the car are counted from the step-wise increments and decrements of the load information. The total number of passenger transfers is redundantly counted from the photocell signals to ascertain the load measurements.

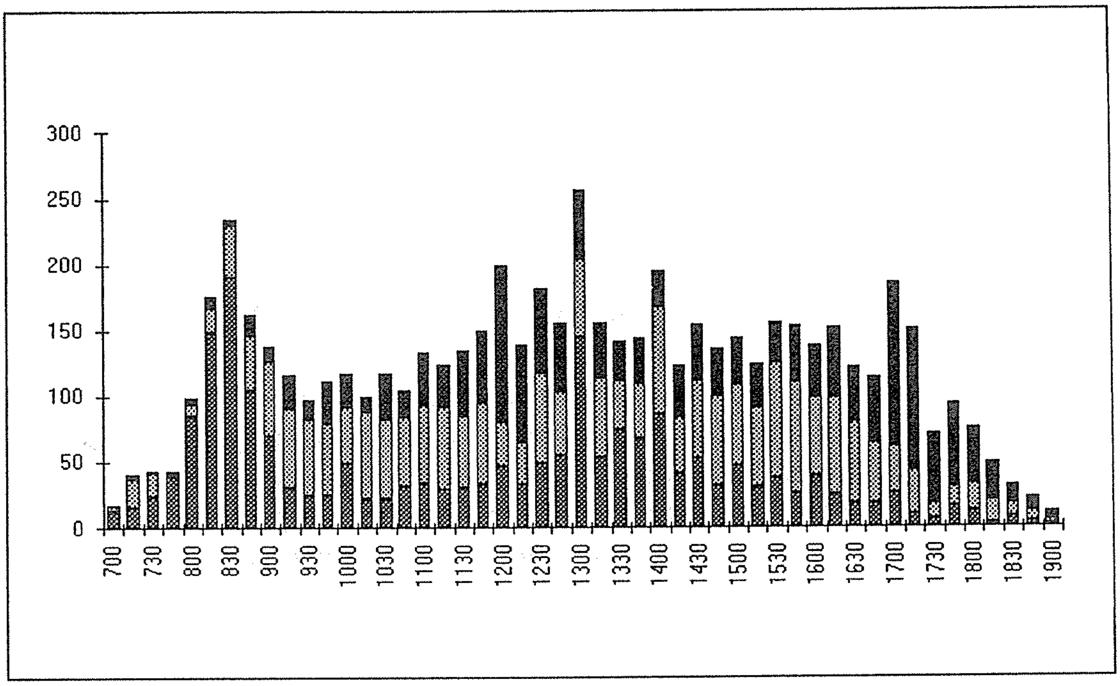

Figure 2. One day statistics of the number of passengers (from bottom: up, interfloor and down traffic components) stored in time slots of 15 minutes.

Reliable prediction of passenger traffic is required to ensure correct control decisions. Although it is naturally impossible to precisely foresee future events, passenger traffic can be forecast rather accurately from measured traffic statistics. The number of passengers is counted over short intervals and stored as Long Term Statistics (LTS) in the computer memory. Day by day, the traffic is learned using an exponential smoothing method, ARRSES (Adaptive Response Rate Single Exponential Smoothing).

Figure 2 shows a traffic pattern measured by the TMS 9000 Traffic Forecaster in an office building in the U.S.A. As shown by the figure, the traffic is most intense during the lunch hour when there is simultaneous up, down and interfloor traffic. Morning Up Peak and evening Down Peak periods can also be seen in the figure.

Defining the traffic pattern

The dominant traffic pattern in a building is continuously determined from the statistical forecasts and short term statistics. Types of incoming, outgoing, interfloor, two way and mixed traffic are defined according to the proportions of incoming, outgoing, and interfloor traffic. The intensity of the traffic is also considered. Four intensity categories are defined: intense, heavy, normal and light.

Simulations make it possible to identify the points where the traffic intensity can be considered to change for example from normal to heavy. The limits between intensity categories are not definite: the certainty of a category grows or diminishes gradually. The categories of traffic intensity and the traffic types are mathematically described using fuzzy logic with membership functions. An example of membership functions for the intensity of incoming traffic is shown in Figure 3. The dominant traffic pattern is defined from a set of 36 fuzzy rules (patent pending). As an example, the fuzzy rule to determine Up Peak is:

IF intensity = HEAVY and incoming traffic = HIGH and outgoing traffic = LOW and interfloor traffic = LOW THEN traffic pattern = HEAVY UP PEAK

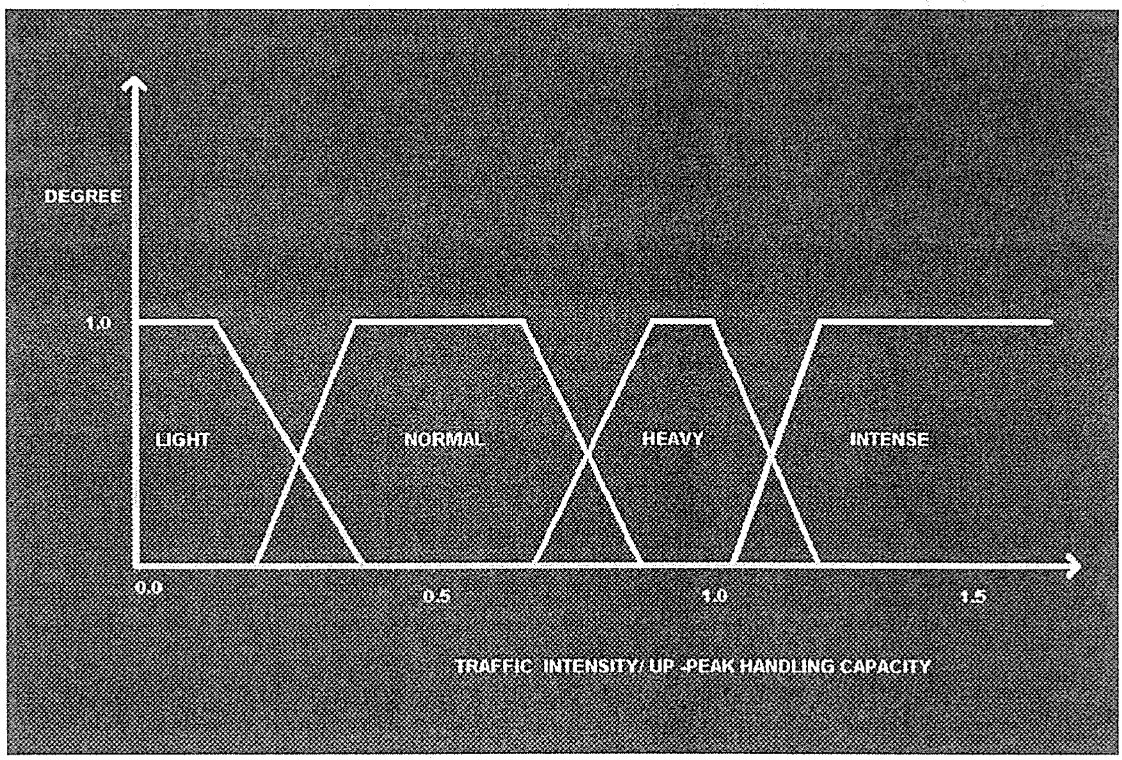

Figure 3. Membership functions for the intensity of incoming traffic.

Intelligent Group Control

Current information on the traffic pattern, complemented by statistical predictions, allows the group control to continuously adjust the hall call service to meet the actual demand.

The service need in various types of buildings is different. In the TMS 9000 control system, passenger waiting time, ride time in the car, and car load can each be given weight to emphasize a desired feature. The by-pass load can be defined separately for each car because elevators within the bank can have unequal car sizes. If the load exceeds the given value, hall calls will be disregarded until the load has decreased below this value.

When the traffic intensity is heavy or intense, strong control actions are needed. According to numerous field measurements, and as seen in Figure 2, the most intense demand pattern in most office buildings is the lunch hour traffic, comprising incoming, outgoing and interfloor components. The TMS 9000 Traffic Forecaster recognizes not only Up Peak and Down Peak but seven separate traffic types with different intensities. The group control favours hall calls serving predominant passenger flows. The traffic intensity at each floor is forecast, and the hall calls are served considering both the hall call times and the predicted passenger arrival rates.

The morning Up Peak traffic can still be problematic in under-elevatored buildings, which is often found to be the case when modernizing old elevator installations. If necessary, the Up Peak handling capacity can be increased by a temporary subzoning arrangement. The passenger waiting times can be reduced by a feature called "Next up", which homes vacant elevators to entrance floors and dispatches them at controlled intervals.

In buildings with multiple entrance floors, proper homing of elevators to various entrance floors has been a difficult task, but the intelligent TMS 9000 control system can handle this by new means: the statistical forecasts of passenger arrivals are utilized to determine how many cars shall be returned to each entrance floor. Better service is also provided for special floors, such as restaurant floors. The starting and stopping times of peak services are determined according to the statistical forecasts and the short term statistics. This is important in reducing passenger waiting times when "Next Up" feature or "Subzoning" are employed.

During light traffic, intelligent parking policy will shorten passenger waiting times. Floors where most of the traffic originates from are identified from the statistical forecasts, and vacant cars are parked there. When the traffic pattern changes, the parking policy is automatically changed by the group control to correspond with the new service demands.

Implementation

Elevator controllers transmit the digital information of car loads (including the number of entering and exiting passengers per floor) to the group control computer. The traffic statistics are stored in a RAM memory with battery backup. Thus, if a power failure occurs, the group control will loose no data. The code for learning the traffic statistics and the set of fuzzy rules are written in object oriented C++ language.

Elevator Monitoring and Command System

The Elevator Monitoring and Command System (EMC) is connected to the elevator controllers through a high-speed Computer Area Network (CAN). The EMC workstations give building managers and maintenance engineers access to numerous graphical and tabular reports on the elevator group performance and control of the system's operation. With the Elevator Traffic display, the exact car loads and the dominant traffic pattern can be seen on the screen.

Passenger Service Level Improvement During Up Peak

To verify the efficiency of the AI software module, three different group control principles were tested with the ALTS simulator [1] during predominantly incoming traffic with a 20% interfloor component. An office building with 16 floors and three entrance floors was used as a test case. The traffic is served by a group of four elevators. The first control was a conventional group control with automatic car returning to the two lowest entrance floors, and the two others were TMS 900+ (without Traffic Forecaster) and TMS 9000 with Traffic Forecaster. The improvement in service quality due to Traffic Forecaster can clearly be seen from simulated passenger waiting times. Floor # 2 is the main entrance floor, but there is relatively intensive incoming traffic from floor # 1 (parking) and floor # 3, too. The arrival intensities from these three lowest floors are 25%, 50% and 25% respectively. The simulation time at every intensity point was 30 minutes.

Average passenger waiting times and average hall call times for all the controls are shown in Figures 4 and 5 respectively. In the figures, the 100% traffic intensity corresponds to the Up Peak capacity. It can be seen from Figure 4 that the passenger waiting times start to increase rapidly when the traffic intensity reaches and exceeds the capacity limit. The same phenomenon cannot be seen so clearly from the average call times in Figure 5.

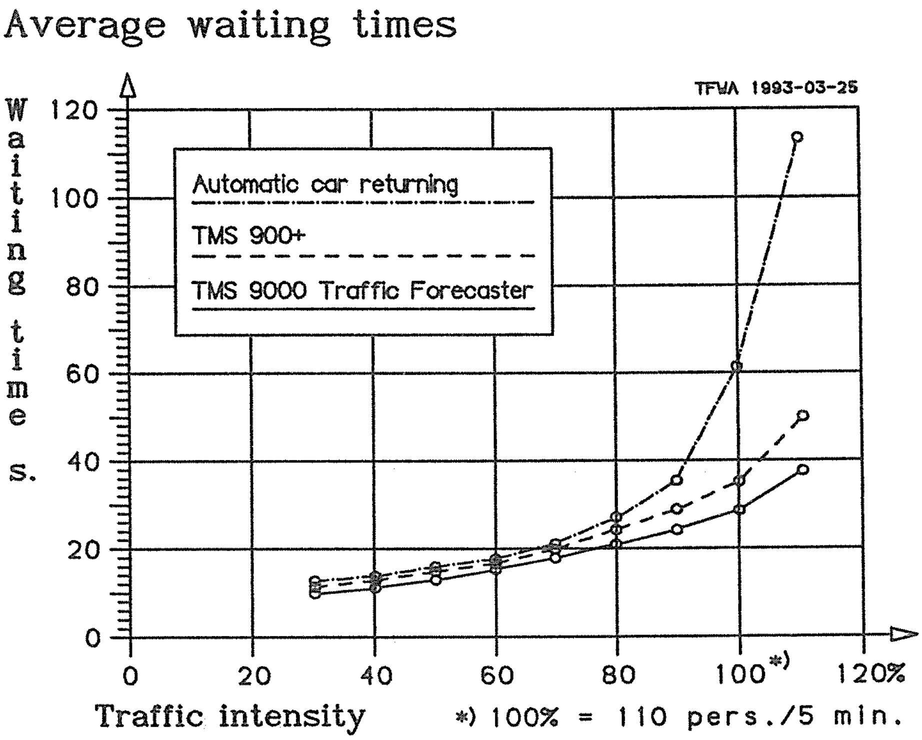

Figure 4. Average passenger waiting times as a function of traffic intensity.

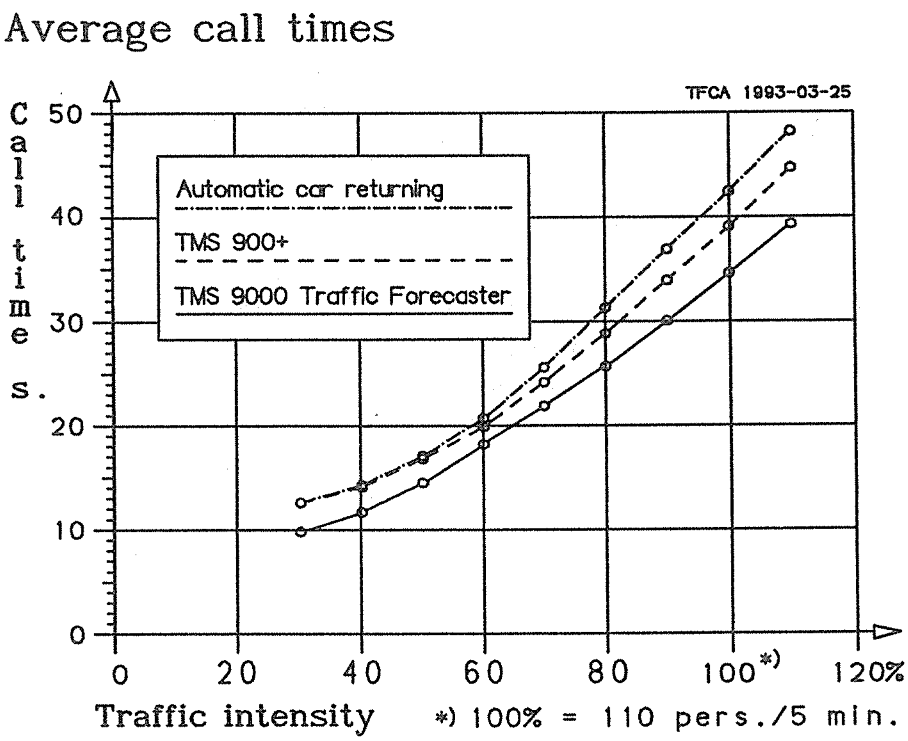

Figure 5. Average hall call times as a function of traffic intensity.

The conventional control returns vacant cars to the two lowest entrance floors when a certain level of traffic intensity has been reached. Traditionally, the Up Peak situation is recognized when car loads exceed a certain limit at the time of leaving the entrance floors. In the simulation, long passenger queues appeared on the second floor, where the average passenger waiting time exceeded the average call time. This can be seen in Figure 6, where the average waiting times and call times are shown for the three entrance floors.

With TMS 900+ and TMS 9000 Traffic Forecaster partially loaded cars running upwards from the lower entrance floors provide collective service for the upper entrance floors. The Traffic Forecaster ensures an even more balanced service to busy floors, because it returns cars to the entrance floors according to their measured traffic flows. Both the relative passenger traffic distribution and the intensity of the traffic affect the number of cars to be returned.

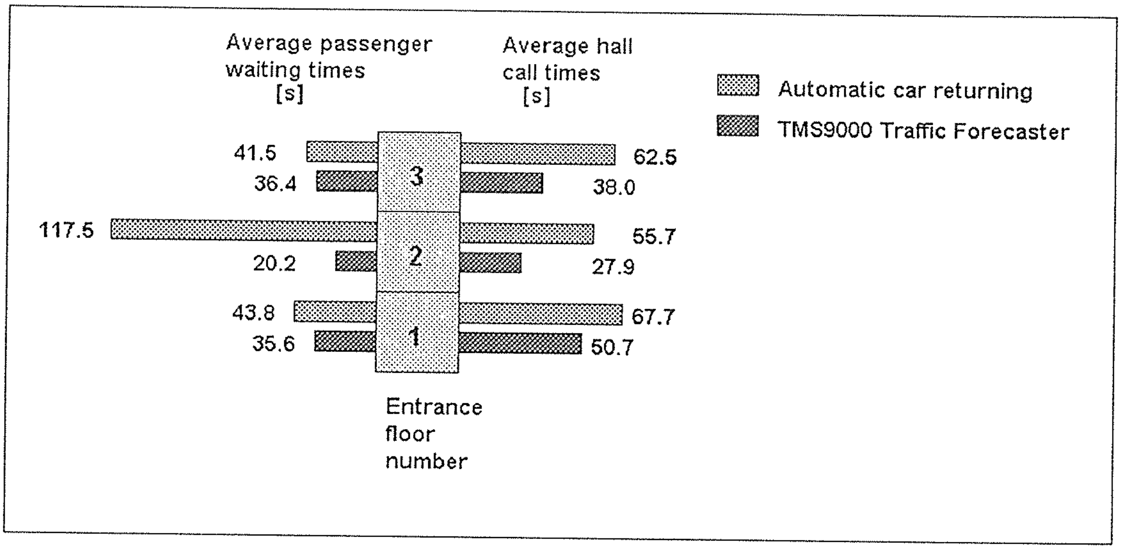

Figure 6. Average call times and passenger waiting times for the three lowest floors at 100 % traffic intensity.

CONCLUSION

This simulated example case proves the importance of considering the number of passengers behind each landing call, and not just the call times. The AI-enhanced control system adapts to the real traffic demand and improves passenger waiting times even more than call times. On the main entrance floor (# 2), the average call time was reduced by 50%, and the average passenger waiting time by 83%.

The example also shows clearly that call time recordings are not enough to verify the passenger service quality provided by an elevator installation. This is especially true in buildings with exceptionally busy passenger arrival floors, on which queuing may cause passenger waiting times much longer than revealed by the call time statistics. Advanced artificial intelligence software packages, such as the one described above, can ensure equitable, high-quality passenger service at all floors of the building.

BIOGRAPHICAL NOTES:

Marja-Liisa Siikonen received her M. Sc. degree in technical physics in 1979, and a degree of Licenciate of Technology in applied mathematics and technical physics from the Helsinki Technical University in 1989. She joined KONE Corporation in 1984, and works at present as a Project Manager in KONE Elevators' Research Center, Hyvinkää, Finland.

Matti Jaakko Kaakinen received his M. Sc. (Eng.) degree from the Helsinki Technical University in 1961. Joining KONE Corporation in 1963, he served in various positions both in Finland and abroad. At present he is the Manager of Market Engineering of KONE Elevators, responsible for international technical sales support, including elevatoring calculations and traffic simulation techniques.

[1] Siikonen M-L., Simulation - A Tool for Enhanced Elevator Bank Design, Elevator World, April, No. 4, 1991.