INDIVIDUAL ELEVATOR PERFORMANCE

V. Quentin Bates, Jr.
Lerch, Bates & Associates, Inc.
Littleton, Colorado

ABSTRACT

Over the past decade, global awareness of elevator performance has heightened. Higher rise applications in Europe, in Asia, in the Mid East... have necessitated consideration of performance potential of planned elevator groupings. Each company and each consultant concerned with suitable elevatoring, have developed standards for evaluating service, and systems for calculating or simulating such potential during project planning. At the same time, pressures have developed for improvement in ride quality and door operation and enhanced safety, while concern for disabled access, especially in the U.S., has resulted in regulations adversely affecting individual car performance.

This paper reviews the theoretical effect that changes in individual elevator operating characteristics can have on elevator performance, specific areas studied are speed, acceleration, jerk, door opening time, door closing time, door type, and, door hold open time.

INTRODUCTION

I know many of you are inclined to academic pursuit, and have probably investigated the effects that changes in individual car performance have on handling capacity and average interval. I had never done such an investigation, personally, but had listened to numerous discussions concerning the adverse impact that increasing door times or reducing acceleration rates to achieve smoother, quieter operation, would have on performance of an elevator group. After some 30 years as a consultant, these erudite discussions finally raised my curiosity to the point of action. As a divertissement for this Congress, I checked the theoretical impact of such changes. I would like to take a few minutes to review theory and the results of performance calculations based on variations in individual car functions.

THEORY

The benchmark calculation for evaluating elevator performance is Round Trip Time. Based on the number of persons transported on an average elevator round trip, Average Intervals, Passenger Handling Capacities, Time to Destination and other measures of service are projected. This Round Trip Time is calculated using appropriate values for the functions that occur as the elevator travels from the terminal floor, loading and discharging passengers, then returns. Obviously the functions involved are:

Loading Passengers
Closing Doors/Door Reversals
Accelerating To Speed
Running
Decelerating To Stop
Opening Doors
Discharging Passengers
Excess Door Hold Open Time

Within those functions, countless observations, measurements and assumptions have been made to set values for these functions in order to reasonably quantify the almost magical ROUND TRIP TIME that is the mathematical basis for performance calculations.

What happens as the values used vary? Let's review quickly, then evaluate the results. For calculation purposes, the following model was used:

Building Levels:	Ground, 2-12
Population:	500 Persons
Elevator Group:	Four Cars
Speed:	2.5 m/s.
Door Type:	Center Opening
Door Size:	1100mm Wide X 2300mm High
Traffic Condition:	Heavy incoming - No down stops

Calculations included the following variations:

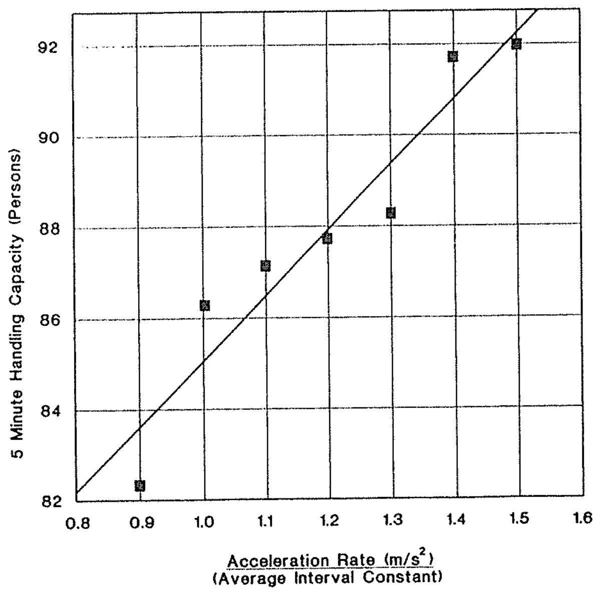
Jerk Values:	1.9 to 2.6 $m/s.^3$
Acceleration Rate:	0.9 to 1.5 $m/s.^2$
Passenger Boarding Time:	1.0 to 1.5 s. per person
Passenger Exiting Time:	1.0 to 1.5 s.
Door Opening Time:	1.4 to 2.0 s.
Door Closing Time:	2.4 to 3.0 s.
Preopening Time:	0.6 to 0.0 s.
Door Hold Open Time:	3.0 to 8.0 s.

MOTION TIME

Motion Time, as used here, is intended to include Jerk, Acceleration and Deceleration, as well as other factors which impact the time required for an elevator to move between floors.

Calculations indicate that Jerk Value, the rate of change of acceleration, has very nominal impact on overall performance. Since that impact cannot be observed or measured, merely calculated, I prefer to leave discussion of Jerk to others.

VARIATION IN ACCELERATION RATE



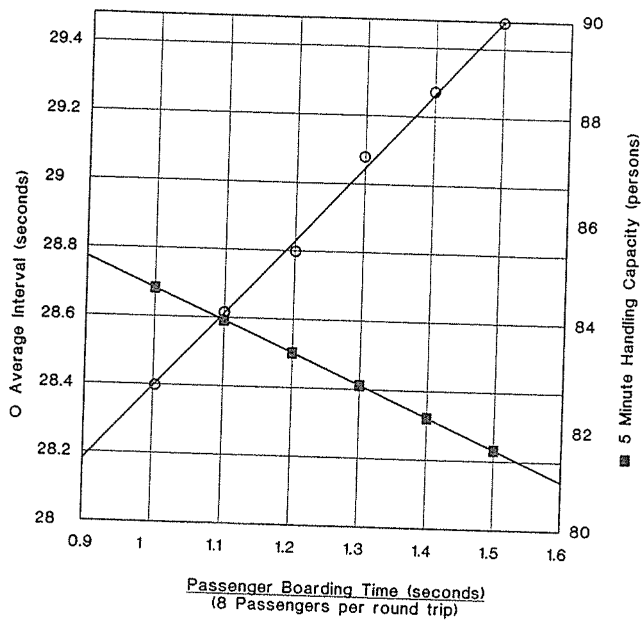
Graph 1 indicates results holding Average Interval relatively constant by varying average persons handling per round trip and calculating 5 minute passenger handling capacity. Varying the deceleration and acceleration rates from 0.9 to 1.5 m/s^2, resulted in a range of almost 10 persons handled in 5 minutes, a potential reduction of over 10% in handling capacity.

If ride quality is achieved by simply reducing acceleration and deceleration rates, performance potential of an elevator group can be significantly impacted if the approach used for this comparative value calculation is truly reflective of the impact of change. Another approach would be to hold the number of passengers constant and calculate changes in both Average Interval and Passenger Handling Capacity. Jerk, acceleration and deceleration are not the only factors affecting motion time. For example, time many be spent in an extended leveling zone when a constant, lower speed is maintained for some distance. This condition frequently exists on direct hydraulic equipment.

In fact, when investigating the effect of timing variations, the number of passengers handling on each round trip was held constant at eight persons. A particular timing function was then valued through a normal range and average interval and passenger handling capacity calculated. Since the number of probable stops is constant through the range of variation, results are linear as shown in the graphs illustrating results.

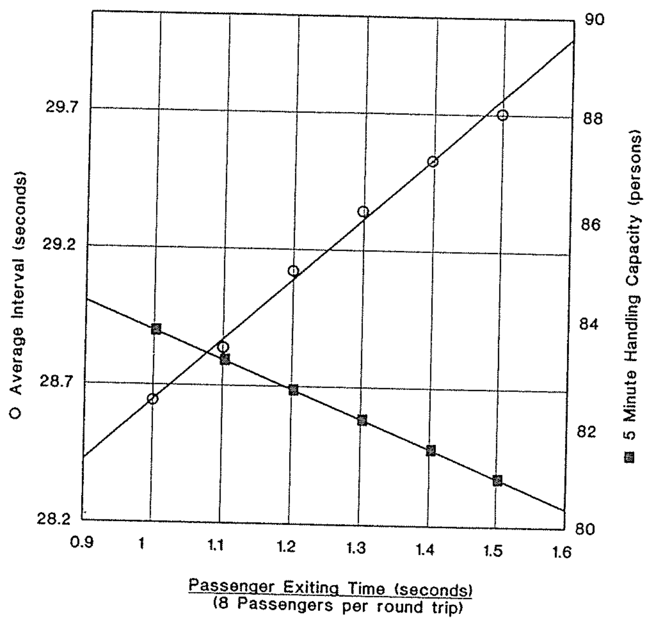
PASSENGER BOARDING TIME

An increase of ½ second in average boarding time increased average interval just over one second (+ 3.9%). Handling capacity was lowered by some three persons in five minutes (- 3.8%)



PASSENGER EXITING TIME

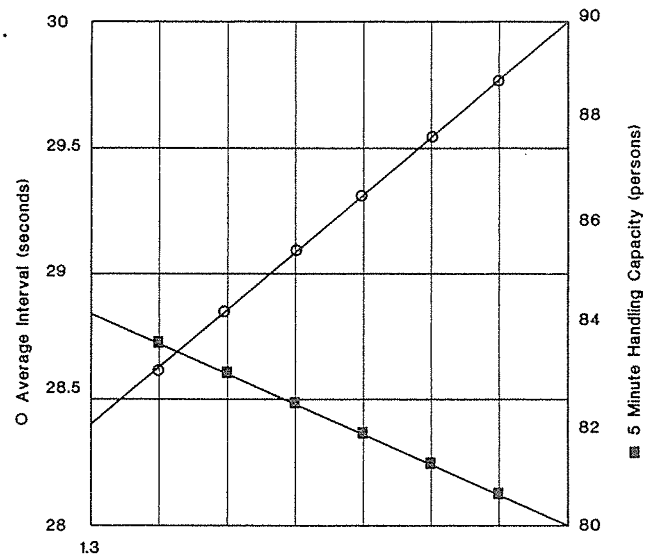
Similar variation in Passenger Exiting Time yields results identical to Passenger Boarding Time.



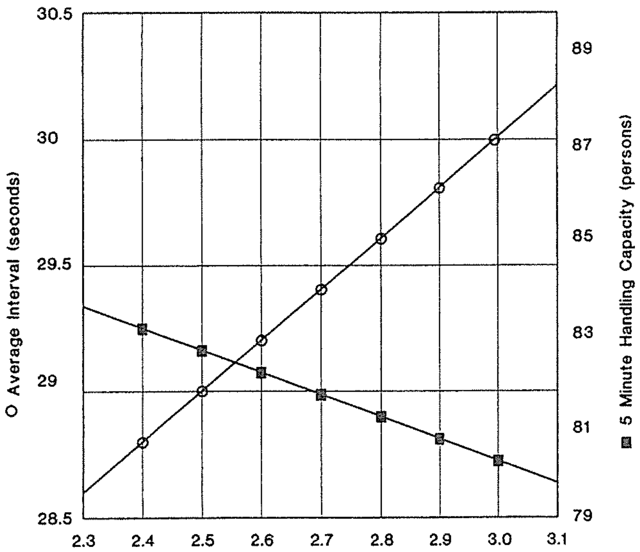
Most elevator engineers recognize that passenger transfer time is affected by the width of the door opening. Wider door openings allow two (or more) persons in the doorway at the same time rather than in a single column resulting in lowered transfer time when a queue exists. This reduction in transfer partially offsets the increase in opening and closing wider, heavier doors.

DOOR OPERATING FUNCTIONS

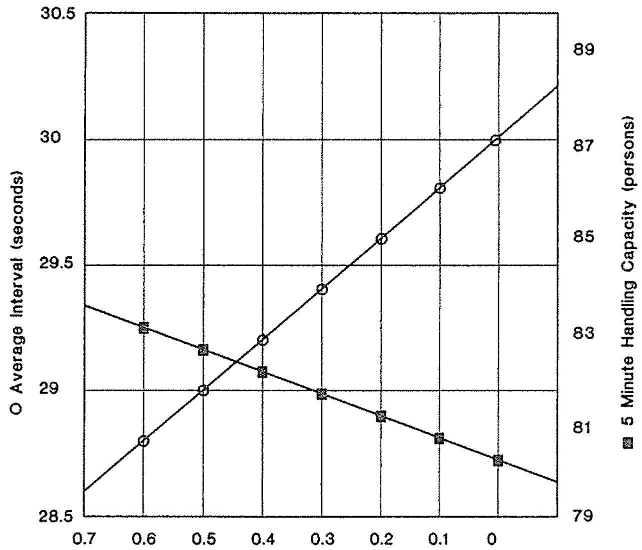
Results for each function are comparable. An increase of 1/2 second in the particular function increases Average Interval by a second and reduces Passenger Handling Capacity by about 3 persons in five minutes. Variations which result from the selection of door type or opening and closing speeds are not reflected in these graphs. Side opening doors require more time to open and close as do slower operating speeds. Table One summarizes comparative times using the 1100mm opening width of our study model:



Door Opening Time (seconds)
(8 Passengers per round trip)



Door Closing Time (seconds)
(8 Passengers per round trip)



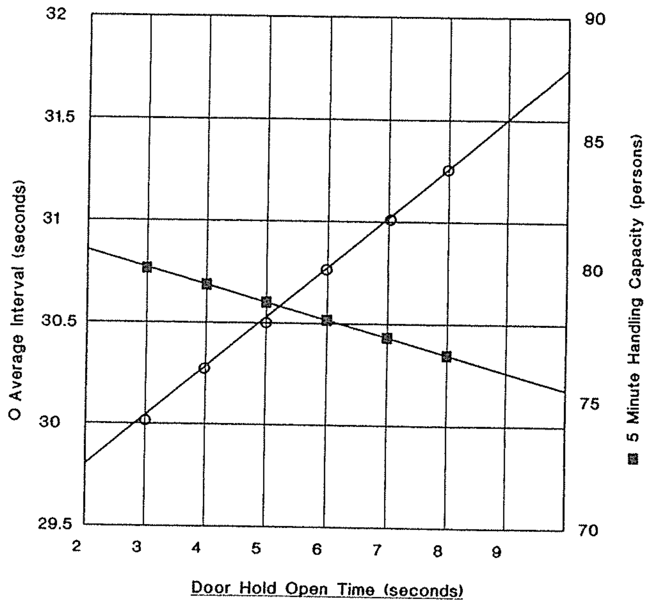
Door Pre-opening Time (seconds)
(8 Passengers per round trip)

Preopening time refers to the common practice of starting to open doors as the car approaches a floor to stop. The added times calculated for door types and operating speeds would not apply in total if doors begin to open while the car is in the leveling zone.

TABLE ONE
DOOR TYPE AND OPERATING SPEED
OPERATING TIME COMPARISON (SECONDS)

DOOR TYPE AND COMPARISON	OPENING TIME		CLOSING TIME
	450mm/SEC SPEED	750mm/SEC SPEED	300mm/SEC SPEED
CENTER OPENING	1.9	1.5	2.5
SIDE OPENING	3.0	2.1	4.1
ADDED TIME/STOP W/S.O. DOORS	+ 1.1	+ 0.6	+ 1.6
% INCREASE	+ 58%	+ 40%	+ 64%
TOTAL INCREASE IN ROUND TRIP TIME WITH STUDY MODEL (5.7 STOPS)	+ 6.3	+ 3.4	+ 9.1

DOOR HOLD OPEN TIME



As a single variation, the duration of door hold open time has the most significant impact on Average Interval and Passenger Handling Capacity of any function studied. Maintaining the round trip passenger load of eight persons, results were calculated using hold open times ranging from 3.0 to 8.0 seconds. Over that five second range, average interval increased over seven seconds (23.8%), while handling capacity was reduced by almost 15 persons in five minutes (18.3%). The need to obtain advance notification of car arrival and travel direction in the United States, where disabled regulations use the distance from hall pushbuttons to arriving car doors as the basis for calculating notification time■, may be very important.

DISCUSSION

Review of individual car performance functions indicates that an increase of one second in average interval, with the particular building and elevator model used, decreases handling capacity approximating 4%. Recognizing that this decrease represents only three persons, relaxation of adjustment of any single element seems relatively innocuous. The dramatic exception being, Door Hold Open Time.

■ Notification Time is measured from car arrival signal activation until initiation of door closing.

The danger is that all performance areas may be relaxed, over a period of time in order to simplify maintenance and adjustment, or to reduce noise and vibration perceived by riding passengers.

What can happen? Assuming constant value of jerk and passenger transfer times, values for other car functions were modified as follows:

Acceleration	1.5 to 1.0 m/s^2
Door Opening	1.5 to 2.0 s.
Door Closing	2.4 to 3.0 s.
Hold Open Time	3.0 to 4.5 s.

Calculated values changed as shown in Table Two:

TABLE TWO
PERFORMANCE MODIFICATION
(5 MINUTES OF HEAVY INCOMING TRAFFIC)

	AVERAGE INTERVAL (SECONDS)	PASSENGER HANDLING CAPACITY (PERSONS)
BASE VALUES (HIGH PERFORMANCE)	21.3	112.6
RELAXED VALUES (LOWER PERFORMANCE)	25.7	93.4
VARIATION	4.4	19.2
% VARIATION	+ 21%	- 17%

These are significant variations, equaling the potential of almost one elevator in our model four car group.

CONCLUSION

This study covers only a simple model. To satisfy a true investigation of the impact that variations in individual car adjustment can have on elevator performance, many models should be similarly evaluated. Still, there is no doubt, even from this single model, that individual car performance is very important and should be considered and measured when evaluating theoretical and actual performance of elevator groups.

Individual car performance is important and should be considered and measured when evaluating theoretical and actual performance of elevator groups.

BIOGRAPHY

Quent Bates is Chairman and CEO of Lerch, Bates & Associates, an international consulting firm specializing in vertical transportation, facade access and materials management. Mr. Bates is an engineering graduate of the United States Military Academy and holds a Masters Degree in Business Administration from the University of Denver. He is a registered Professional Engineer, active in professional organizations and groups, occasional speaker and writer on elevator topics and founding member of the IAEE.