Performance Measurement of Vertical Transportation Equipment

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ABSTRACT

The author is Michael V. Farinola President of M V Farinola, Inc. an elevator systems consulting firm from Wilmington, Delaware USA. The presentation will include discussion on U.S. Industry standards (NEII and ASME) as well as consultant and owner (end user) expectations on performance. The paper will include the most recent Methodology presently employed by consultants and most major manufacturers to measure lift performance. The methodology discussion will include a brief description of hardware utilized to collect data, including Tri-axis data logger, Tachometer, Traffic study computerized tools (simulated performance) and data collection forms for on site use (to calculate actual performance). Some discussion of Generally Accepted Performance Criteria (Parameters) for specific lift components will be presented as well. These criteria will include a short review of such areas as Velocity, Jerk, Acceleration, Door Performance, Transfer time, Handling Capacity, Intervals, Round trip times, Probable Stops, Waiting times and Mean time between equipment shut downs.

1. HISTORY

The Elevator industry has long been anchored in Engineering principals, as well it should. The design, manufacturing, installation and, soon to be, maintenance are closely governed by the ASME A17.1 Code in the USA. (Presently under harmonization with the B44 Canadian code to become the North American Standard). These codes are designed to insure safety and not original design performance. However it did establish average door closing time based on kinetic energy of 7 ft poundal for average weight hollow metal doors. Along the same lines the ASME Code limited the door torque to less than 30 pounds force.

It had long been the responsibility of the maintenance company to insure that the elevator performed as it was originally designed. As the North American industry became more diverse with the growth of independent 'service only' elevator companies, the focus moved away from 'performance based' maintenance to 'low or lower cost' maintenance. This was market driven to a great extent by the high inflation of the 70's and lift owner's concerns with bottom line results in his or her's own business operations.

As the paradigm shift played out it became apparent that owners were starting to question why traffic handling capabilities had begun to change in their buildings. Passengers were loading up in the lobbies during high demand periods like never before and equipment anomalies were becoming more frequent as well as the frequency of callbacks (customer calls for service) and equipment shut downs. The owner no longer wanted the elevator maintenance company to answer these questions and looked to Engineering firms and independent elevator consultants to evaluate their equipment and submit a report as to their findings. The original reports were as diversified as the number of companies providing them.. Never the less what began to develop were first the identifiable performance areas which needed to be measured. They were:

1. **Door Operation**
2. **Dispatching (Zoning & Waiting Time)**
3. **Car Speed**
4. **Velocity Transition Time (Acceleration and Deceleration)**
5. **Ride Quality**

Ride quality, Velocity Transition Time, Dispatching were still subjective based almost entirely on the consultants tactile evaluations. There were no industry standards established in the 1970's and it was common to have a consultant report state that the " . . . ride quality was unacceptable and the door operation too slow (or fast)." Needless to say there was a need to incorporate the merits of quantifiable and documentable data. But practical application of measurements needed to be applied as well. We wouldn't want to see a request to adjust a door operation .5 seconds faster on a hydraulic service elevator.

In the 1980's a number of devices and methodologies showed up in the marketplace that tried to address these issues and more and more consultants began using door open and close speed standards, albeit their own, in their specifications. The standards could vary from consultant to consultant depending on the source of his information and the degree of his own field testing and verification. Traffic studies were performed using computerized analyzers directly connected to controller circuits, and monitored specific car and hall switch and button registration time. All of the so called traffic analyzer's were measuring hall button registration time and not the traffic handling capacity. Both handling capacity and hall registration time are valuable measurements individually. However, together they provide a more complete picture of the equipments performance. Early in the 1990's came accelerometers. Those specifically designed for elevator/escalator application were developed to measure ride quality and included sound readings, acceleration and deceleration profiles as well as jerk (the rate of change of acceleration) velocity, distance traveled and the capability of ISO filtering .

2. STANDARDS

As the North American consultants kept honing their performance standards on several fronts the Elevator Industry was seeking to develop a standard through their Industry Association NEII (National Elevator Industry Inc.) NEII publishes the Vertical Transportation Standards which is a comprehensive guide to the various types of Elevators, the space they require, how they fit into buildings and the support needed from the building to provide elevator service. In 1992 the NEII Board of Directors authorized formation of a Committee "...to develop standards that can be used by the industry as guidelines for elevators and escalators to achieve acceptable performance while maintaining code and safety compliance." In 1994 as a supplement to the Vertical Transportation Standards were issued containing performance standards for new and modernized equipment. It was a daunting task given the great array of equipment, liability, and safety considerations. The end result was the very well thought out performance terminology and standards matrix.

The Vertical Transportation Handbook-Third Edition (Strakosch 1998) was edited by, its previous editions author, George R. Strakosch with acknowledgments . It is considered the book on elevatoring in the United States. It complimented the NEII matix in basic terminology and methodology but it had some slight variations in the performance standards on some of the criteria. In our field audits we have compared the data we measure with the standards of both NEII, Strakosch and ASME Code and developed the following standard:

	Hydro*	Geared**	Gearless***
Sound			
2.1 Door Open, Close, Reversal (NEII)	*70 dBA*	*67 dBA*	*64 dBA*
2.2 In Car at rated speed fan off (MVF)	*65 dBA*	*60 dBA*	*60 dBA*
2.3 In stopped car door closed fan off. (MVF)	*55 dBA*	*55 dBA*	*55 dBA*
2.4 In Machine room..(MVF)	*75 dBA*	*70 dBA*	*70 dBA*
Motion			
2.5. Contract Speed Regulation (MVF)	±2% Static control	±5% Relay control	
2.6 Stopping Zone -Leveling (MVF)	± ⅛ in. Static control	±¼in. Relay control	

	Hydro*	Geared**	Gearless***
2.7 Acceleration Deceleration (Strakosch)	*3.5 ft/sec²*	*3.5 ft/sec²*	*4.5 ft/sec²*
2.8 Ride quality - Vertical vibration (NEII)	*30mg*	*20mg*	*15mg*
Horizontal vibration SS/FB	*30mg*	*25mg*	*25mg*
Timing			
2.9 Motion Time -Brake to Brake† (Strakosch)	*8.7 sec*	*5.7sec*	*4.4sec.*
2.10 Door Open Speed ‡(Strakosch)	*1.7sec*	*1.7sec*	*1.7sec*
2.11 Door Close Speed ‡(Strakosch)	*2.4sec*	*2.4sec*	*2.4sec*
2.12 Door Dwell -Hold open Time (MVF)			
2.12.1 Car Call	*1.5-3sec*	*1.5-3sec*	*1.5-3sec*
2.12.2 Hall Call	*4.0-6sec*	*4.0-6sec*	*4.0-6sec*
2.12.3 Lobby Call	*5.0-10sec*	*5.0-10sec*	*5.0-10sec*
2.12.4 Car Door Reversal	*.5-1sec*	*.5-1sec*	*.5-1sec*
2.13 Nudging ⊛(MVF)	30-60sec	30-60sec	30-60sec
2.14 Performance Time ⊛⊛ (MVF)	*13.3sec*	*10.sec*	*9.5sec*

****2500@125fpm 3stops **3500@350fpm 10stops ***3500@700fpm 15 stops***
†Based on 12ft floor heights and add of .5sec for leveling hydro and .75sec leveling traction
‡ Based on Door size of 7'Height 42" Width SSCO and average weight hollow metal doors. Values shown are within the 7-ft-poundal ASME kinetic code limitations.
⊛ Measured from start of continuous activation of door reopening device until audible nudging signal and start of door close at reduced speed.
⊛⊛ Performance Time includes .5sec lag time from point interlock made up to car motion.

The owner or Building Manager who represents the end user, i.e. the riding public, has always placed high priority on controlling the number of callbacks per unit per year, reducing the passenger waiting times (hall call registration), and improving response time of the service company i.e. from customer call to dispatcher contacting a mechanic [T^1] to the mechanic arriving at the job [T^2], to the time to return the car to service [T^3] the following are based on average US city:

Callback Rate (Equipment related only)

2.15	Center City High Rise	< 3/unit/year
2.16	Suburban Office	< 3/unit/year
2.17	Hospitals	< 7/unit/year
2.18	Universities	< 6/unit/year
2.19	Dormitories	< 8/unit/year

Average Hall Call Registration Time

2.20 Microprocessor controlled equipment *75% of calls <20 sec*
95% of calls <35 sec

2.21 Relay based controlled equipment *70% of calls <30 sec*
90% of calls <45 sec

Service Company Response Time (Regular working hours typical US City)

2.22 Customer Call to Page *[T^1]= 3-5 min*
2.23 Customer Call to Mechanic Pick up call *[T^2]= 22-25 min*
2.24 Customer Call to Unit Placed Back in Service *[T^3]=120-150 min*

3. TOOLS

In order to perform the performance audit there are several tools that are used and I would like to list them here:

3.1 Tri-axis Data logger and software analyzer by Performance Measurement Technologies
3.2 Spring Gage to measure door force
3.3 Stop Watch for all timing measurements to the tenth of a second.
3.4 25' retractable measuring tape.
3.5 Non conductive flashlight
3.6 Elevator Survey forms
3.7 Tachometer (Digital or Analog) for measuring Velocity
3.8 Sound Meter
3.9 Simulator to compute Group Performance Parameters

The most significant of these tools is the tri-axis accelerometer which along with its software program graphically demonstrates much more than just the vertical, front to back and side to side vibrations. Through manipulation of the data via formulas the velocity, jerk, acceleration, distance are displayed in either ISO or Raw data graphically. The data can be scaled automatically or manually. Reference limits can be set by the operator so a specific performance limit can easily be can be displayed. Fast Fourier Transform (FFT) is a powerful troubleshooting tool which provides amplitude and frequency information about the vibration of interest. Root Means

Squared (RMS) function provides analysis of the chosen acceleration channel. Three methods of filtering are provided, first ISO for Whole body horizontal and vertical vibration (human response characteristics specified in ISO 8041), second, High Pass filter (1.5Hz cutoff) and Low Pass Filter (approximately 10Hz cutoff). This is based on the default Sample rate of 256 SPS. The filter cutoff frequency rate for High & Low Pass at 512 SPS is 3 and 20Hz respectively.

Another important tool is the elevator survey forms which help to compile the timing data in an organized way. Entering the data on Lotus Spreadsheet allows automatic averaging of the three trials and summing up the applicable components to arrive at the performance time. It will also calculate the velocity deviations. This spreadsheet is a time saver.

The simulator is the last but not the least of these tools I will discuss. It's a software program that allows the user to do some 'what if's' on any type of project. Once you have identified what type of installation it is you use the Vertical Transportation Handbook criteria for handling capacity and interval as your target and manipulate the variables you can plug-in. The Elevator Group Performance Parameters Form is a hard copy document of the required building floor heights, population per floor and the selected variables of performance data, based on the door size and speed of the elevator, loading of the car, added trip time, or hospital vehicles. The software then calculates the Round trip time, Interval, Handling Capacity High call reversal and probable stops. This is not only a powerful tool for specifying the correct number size and type of elevator in a new building but can also be used in an existing building to ascertain probable traffic improvements if a modernization were to be done.

4. CONCLUSIONS

It would be useful to establish a standardized performance measurement that was not too conservative but not unrealistic either. I believe this paper brings together the correct balance of what is currently available. Like any standard it must be applied taking into account all the job specific variables that may have a practical affect on achieving the standard. Rather than modifying the standard the analysis should discuss those variables within the context of the standard and make a determination if a practical solution to achieving the standard is readily achievable. The standard should be a work in process. Always reflecting newer technology capabilities of performance and measurement.

The Performance analysis of an elevator system can help to identify the reasons why a system appears to be faltering. Most certainly with the latest in performance measurement tools and reference guides you can accurately identify the weak link(s) in a system and make the proper recommendation to the customer.

There is much more that we could discuss. Customer requirements, In- car traffic studies , computerized traffic analyzers. different door operator technologies, maintenance processes that affect performance, the list goes on. This is a very brief discussion on a topic that deserves a great deal of dialogue. I welcome your comments.

5. REFERENCES

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ELEVATOR SURVEY DATA
DATE: 11/18/99

BUILDING NAME: Carvel State Office Building
ADDRESS: 810 French Street Wilmington, DE

	Car 1	Car 2	Car 3	Car 4	Car 5	Car 6
DO1	2.6	2.2	3.2	3.8	2.6	2.48
DO2	2.7	2.1	3.2	3.7	2.4	2.28
DO3	2.8	2	3.1	3.9	2.5	2.5
DO AVG	***2.70***	***2.10***	***3.17***	***3.80***	***2.50***	***2.42***
DC1	3.5	3.5	3.6	4.1	3.6	3.75
DC2	3.4	3.3	3.5	3.9	3.65	3.78
DC3	3.5	3.35	3.6	4.15	3.62	3.56
DC AVG	***3.47***	***3.38***	***3.57***	***4.05***	***3.62***	***3.70***
DDC1	3.3	3.7	3.2	5.15	3.3	8.97
DDC2	3.4	3.7	3.4	5.3	3.4	9.25
DDC3	3.3	3.7	3.3	5.21	3.22	9.4
DDC AVG	***3.33***	***3.70***	***3.30***	***5.22***	***3.31***	***9.21***
DDH1	3.4	3.8	3.6	6.9	3.7	9.7
DDH2	3.5	3.8	3.6	6.6	3.65	9.84
DDH3	3.5	3.8	3.6	6.9	3.68	9.6
DDH AVG	***3.47***	***3.80***	***3.60***	***6.80***	***3.68***	***9.71***
DDL1	15	30	20.5	7.2	20.7	10.2
DDL2	14.8	15	20	7.3	20.5	10.8
DDL3	15	0	19.8	7.1	20.3	10
DDL AVG	***14.93***	***15.00***	***20.10***	***7.20***	***20.50***	***10.33***
DDR1	0.8	1.1	0.9	0.4	0.63	0.52
DDR2	0.7	1	0.8	0.5	0.53	0.5
DDR3	0.3	1.1	0.9	0.6	0.57	0.51
DDR AVG	***0.60***	***1.07***	***0.87***	***0.50***	***0.58***	***0.51***
B-B U1	5.4	7.1	5.5	8.83	6.9	18.56
B-B U2	5.3	6.8	5.4	8.93	7.2	18.87
B-B U3	5.2	6.8	5.5	8.89	7.1	18.78
B-B U AVG	***5.30***	***6.90***	***5.47***	***8.88***	***7.07***	***18.74***
B-B D1	5.4	5.3	5.7	8.5	5.8	15.37
B-B D2	5.2	5.2	5.7	8.77	5.7	14.38
B-B D3	5.2	5.3	5.8	8.66	5.6	14.85
B-B D AVG	***5.27***	***5.27***	***5.73***	***8.64***	***5.70***	***14.87***
TRANS/LAG TIME	2	2	2	2	2	2
PERF TIM U	***13.47***	***14.38***	***14.20***	***18.73***	***15.19***	***26.85***
PERF TIM D	***13.43***	***12.75***	***14.47***	***18.49***	***13.82***	***22.98***
DFORCE NML	24	18	20	25	18	25
DFORCE NUD	N/A	N/A	N/A	N/A	N/A	N/A
NUDGE TIME	15.1	9.2	10.1	11.6	9.4	not working
DOOR TYPE	Center Opening	Center Opening	Center Opening	Center Opening	Center Opening	2 Spd Side Opg.
CAR SPD UP	508	498	506	509	508	320
DEVIATE UP	***1.60%***	***-0.40%***	***1.20%***	***1.80%***	***1.60%***	***-8.57%***
CAR SPD DN	511	507	506	509	507	348
DEVIATE DN	***2.20%***	***1.40%***	***1.20%***	***1.80%***	***1.40%***	***-0.57%***
RATED SPD U	500	500	500	500	500	350
RATED SPD D	500	500	500	500	500	350
CAPACITY	4000	4000	4000	4000	4000	4000
STOPS	12	12	12	12	12	12
REG. NUM.						
SAFETY TEST	4/94	4/94	4/94	4/94	4/94	12/94
INSP. DATE						

File Name:CarvelStateOfb.1;

M V FARINOLA, INC.

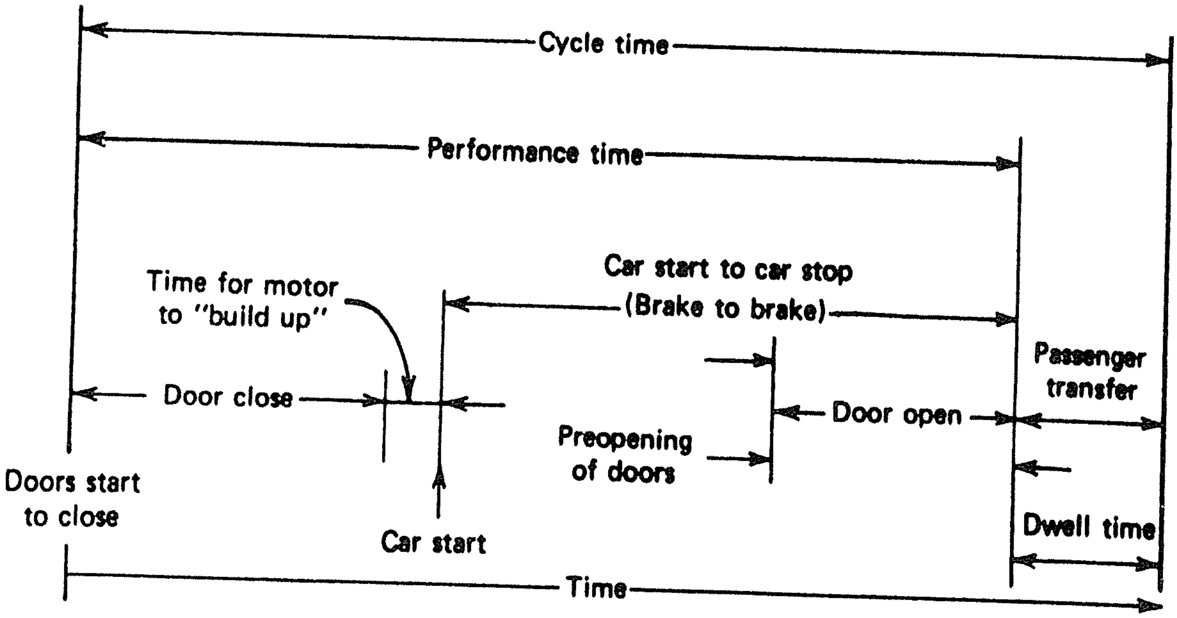
ELEVATOR GROUP PERFORMANCE PARAMETERS

LOCATION: ____________________

FLOORS ABOVE LOBBY:	______	FEET	POPULATION PER FLOOR:	______	PEOPLE
LOBBY HEIGHT:	______	FEET	MFG. OF CONTROLS:	______	
TYPICAL FLOOR HEIGHT:	______	FEET	MFG. OF DRIVE:	______	
EXPRESS ZONE HEIGHT:	______	FEET	NUMBER CARS/GROUP:	______	
DOOR TIME:	______	SECONDS	CAR SPEED:	______	FPM
12 FOOT FLIGHT TIME:	______	SECONDS	CAR CAPACITY:	______	LBS
CAR ACCELERATION:	______	FT/SEC^2	UP CAR LOADING:	______	PEOPLE/CAR
HIGH CALL REVERSAL:	______		DOWN CAR LOADING:	______	PEOPLE/CAR
UP PROBABLE STOPS:	______		ADDED TRIP TIME:	______	SECONDS
DOWN PROBABLE STOPS:	______		HOSPITAL VEHICLES:	______	/5 MIN.

** RESULTS **

ROUND TRIP TIME	______	SECONDS	HIGH CALL REVERSAL	______
INTERVAL	______	SECONDS	UP PROBABLE STOPS	______
UP HANDLING CAPACITY	______	/5 MINUTES	DOWN PROBABLE STOPS	______
DOWN HANDLING CAPACITY	______	/5 MINUTES		


Cycle time
Performance time
Car start to car stop
(Brake to brake)
Time for motor
to "build up"
Door close
Preopening
of doors
Door open
Passenger
transfer
Doors start
to close
Car start
Dwell time
Time