Project Iteration 0 – Measure a Real Elevator

SYSC 3303-L2O: Group 7

Experimental procedure

Objective

The objective was to gather and record timing data for the time it takes an elevator to move between floors and to load/unload car. We decided to use the elevators located in the Canal Building during minimal usage hours for optimal consistency and maximize efficiency.

Questions

We are looking to determine the maximum speed of the elevator, the rate of acceleration for the elevator, and the average loading/unloading time.

Assumption

A difference in height of 4 meters between each floor.

Observation

The approach we took was to get a variety of times by going onto multiple floors and noting the time to travel between various floor differences, as seen in **Table 0.1**. For most measurements, we took 6 measurements of the same type to add some statistical backing in our findings. We also collected the boarding/exit time for when passengers would ideally load and unload the elevator car, as seen in **Table 0.2.**

Data reduction methods and results

Analyze Data

Interpreting the data. We decided to perform a geometric mean of the trials as it is the most appropriate for series that exhibit serial correlation meaning that one time frame will affect another timeframe. This is the case when we measured floor-by-floor as opposed to traveling multiple floors without stopping. Performed a standard deviation based on sample sized. However, the arithmetic and geometric means did not really differ dramatically in our dataset. Then we perform a confidence interval with an $\alpha = 0.05$ for our sample size to satisfy the common 95% benchmark for confidence.

Sample Calculations

We measured for a difference of one (1) floor the distance between floors is 4 meters and the time travel is (10.479±00.242) s. And our largest timeframe was measured for six (6) floors difference giving us as travel time of (22.187±00.387) s. Therefore, we can assume that the maximum velocity can be represented as the following equation,

$$\Delta v = \frac{\Delta d}{\Delta t} = \frac{(6\ floor)(4\ \frac{m}{floor}) - (1\ floor)(4\ \frac{m}{floor})}{22.187\,\mathrm{s} - 10.479\ s} = 1.708\,\frac{m}{s}$$

However, since this was our maximum range, we can assume that 1.708 m/s is maximum velocity.

We assumed to measure the time it takes to move between two adjacent floors and time it takes to move multiple floors. And, assuming that initial velocity is 0. We can model the relationship between velocity and distance in the following equation;

$$\Delta d = \left(\frac{v + v_0}{2}\right) t \Rightarrow t = \frac{\Delta d}{\left(\frac{v + v_0}{2}\right)} = \frac{4\ m}{\left(\frac{\left(1.708\,\frac{m}{s} + 0\right)}{2}\right)} = 4.676\ s$$

Thus, using the equation for acceleration,

$$\Delta a = \frac{\Delta v}{\Delta t} = \frac{1.7108\,\frac{m}{s}}{4.6762\ s} = 0.365\,\frac{m}{s^2}$$

Interpretation of data (synthesis) and discussion

Conclusion

Therefore, we can state that the maximum speed of the elevator is (1.708±0.895) m/s. The rate of acceleration for the elevator to be (0.365±0.112) m/s^2. And the average loading/unloading time to be (4.766±0.085) s, as seen in **Table 0.3.** Reference **Table 0.4.** for a tabulated summary of requested parameters outline as per objective requirement.

There was quite a handful of assumptions that went into interpreting and applying real world dynamics towards theorical predictions and relationships. Note that real elevators accelerate and decelerate as that start up and stop, so the time it takes to move between two floors depends on whether the car needs to stop or start. From the raw data, we made some mathematical and statistical trade-offs to best highlight the main objective to be able to measure tangible metrics of real-time mechanics and attempt to translate them into real-time process that can be executable via a code source. There are many edge cases that were not captured due to time and resource constraints. However, this just highlights the minute details that contribute to creating real-time systems.

Table 0.1. Collected sample timing between different floors with details on starting floor, direction, and car button pressed on the elevator.

Trial No.	Time	Floor Button	Starting Floor	Car Button
	hh:mm:ss.mmm	Up/Down	n	n
Floor diff = 1				
1	00:00:10.150	Up	1	2
2	00:00:10.200	Up	2	3
3	00:00:10.660	Up	3	4
4	00:00:10.580	Up	4	5
5	00:00:10.600	Up	5	6
6	00:00:10.700	Up	7	7
GEOMEAN	00:00:10.479			
STDEV	00:00:00.242			
CONFIDENCE	00:00:00.254			
Floor diff = 2				
1	00:00:12.530	Up	1	3
2	00:00:12.210	Up	4	6
3	00:00:13.090	Up	5	7
4	00:00:12.420	Down	4	2
5	00:00:12.190	Down	5	3
6	00:00:13.140	Down	6	4
GEOMEAN	00:00:12.591			
STDEV	00:00:00.422			
CONFIDENCE	00:00:00.443			
Floor diff = 4				
1	00:00:17.440	Up	3	7
2	00:00:17.340	Up	2	6
3	00:00:17.570	Up	2	6
4	00:00:16.530	Down	7	3
5	00:00:17.090	Down	7	2
6	00:00:17.180	Down	6	2
GEOMEAN	00:00:17.188			
STDEV	00:00:00.367			
CONFIDENCE	00:00:00.386			
Floor diff = 6				
1	00:00:22.420	Up	1	7
2	00:00:22.310	Down	7	1
3	00:00:22.520	Up	1	7
4	00:00:21.450	Down	7	1
5	00:00:22.330	Up	1	7
6	00:00:22.110	Down	7	1
GEOMEAN	00:00:22.187			
STDEV	00:00:00.387			
CONFIDENCE	00:00:00.406			

Table 0.2. Collected data for the boarding and exit times of the elevator.

Trial No.	Boarding/exit Time	Door Open + Idle Time	Load/Unload Time
1	00:00:08.070	00:00:03.330	00:00:04.740
2	00:00:08.090	00:00:03.350	00:00:04.740
3	00:00:08.010	00:00:03.360	00:00:04.650
4	00:00:08.020	00:00:03.110	00:00:04.910
5	00:00:08.120	00:00:03.360	00:00:04.760
6	00:00:08.130	00:00:03.340	00:00:04.790
GEOMEAN	00:00:08.073	00:00:03.307	00:00:04.766
STDEV	00:00:00.050	00:00:00.098	00:00:00.085
CONFIDENCE	00:00:00.053	00:00:00.103	00:00:00.089

Table 0.3. Summary table of all the statistical analysis performed on the data of the timing between elevator floors collected with sample size = 6 and $\alpha = 0.05$.

Floor difference	GEOMEAN hh:mm:ss.mmm	STDEV hh:mm:ss.mmm	CONFIDENCE hh:mm:ss.mmm
1	00:00:10.479	00:00:00.242	00:00:00.254
2	00:00:12.591	00:00:00.422	00:00:00.443
4	00:00:17.188	00:00:00.367	00:00:00.386
6	00:00:22.187	00:00:00.387	00:00:00.406
Boarding/exit	00:00:08.073	00:00:00.050	00:00:03.651
Door Open	00:00:03.307	00:00:00.098	00:00:00.103
Load/Unload	00:00:04.766	00:00:00.085	00:00:00.089

Table 0.4. Summary table of results and interpretation calculated from raw metric date of the elevator times. NB. Error values were calculated using propagation of uncertainty.

	VALUE	ERROR
AVG SPEED [m/s]	1.708	± 0.895
d TIME [s]	4.676	± 0.111
ACCELERATION [m/s2]	0.365	± 0.902
LOAD/UNLOAD [s]	4.766	± 0.085