SYSC 3303 - Iteration 0

Group L1G3
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1. Important Elevator Events with Confidence Intervals

Elevator Name: Canal Building Elevators

Number of Floors: 7

Table 1: Calculating the mean, variance, and standard deviation of the elevator data.

Floor Number	Doors opening (in seconds)	Boarding time (in seconds)	Door closing (in seconds)	Going up (in seconds)	Going down (in seconds)
1	2.53	5.87	4.05	6.71	-
2	1.94	6.09	3.90	7.05	6.53
3	2.77	5.95	4.05	7.06	6.91
4	2.20	4.91	4.02	7.55	7.46
5	2.06	6.07	3.93	7.39	7.38
6	2.12	6.02	4.03	7.58	7.45
7	1.73	6.13	4.15	-	7.08
Mean ($\overline{X}$)	2.193	5.863	4.019	7.223	7.135
Sample Variance (S^2)	0.125	0.184	0.007	0.116	0.137
Standard Deviation (S)	0.353	0.429	0.083	0.341	0.370

1.1 How are these times measured

To measure the elevator doors opening, the timer would start as soon as the doors opened until they reached the fully open position. Measuring the doors idling, the timer started when the doors fully opened and stopped when the doors began to close. To get the time of doors closing, the timer would start when the doors stopped idling and would stop when the doors fully closed. Measuring the time it took for the elevator to go up started when the timer felt the movement of the elevator begin. The timer would stop when the movement of the elevator stopped. The same measurement technique was used for going down as well. No open door or close door buttons were used during the timing process.

1.2 How are confidence intervals calculated

$$\overline{X} - t_{a/2,n-1} \cdot \frac{S}{\sqrt{n}} < \mu < \overline{X} + t_{a/2,n-1} \cdot \frac{S}{\sqrt{n}}$$

Given a calculated mean time value and a significance level (α) of 5%, the confidence interval is found by using a t-test. A 5% significance value was chosen because our measurements were all to the hundredth of a second, meaning we could not pick a significance lower than 1%. Since a two-tailed t-test divides significance by 2, 5% is the most accurate significance level (on the t-test table) we could select. A t-test is used because the standard deviations of the population of all elevator events are unknown and we assume that the measurements taken are normally distributed.

Here is an example of how the confidence intervals were calculated:

Looking at the t table: $t_{0.025,\,6} = 2.447$

For example for doors opening the confidence interval is as follows:

$2.193 - 2.447 * (0.353/\sqrt{7}) < \mu < 2.193 + 2.447 * (0.353/\sqrt{7})$

So with 95% confidence, the door closing times is in the following range: $1.87 < \mu < 2.52$

Using this method here is a summary of the calculated confidence intervals:

Table 2: Important elevator events calculated with a 95% confidence interval.

Action	Minimum Time (seconds)	Mean (seconds)	Maximum Time (seconds)
Doors Opening	1.87	2.19	2.52
Elevator is Idle	5.47	5.86	6.26
Doors Closing	3.94	4.02	4.1
Going Up	6.91	7.22	7.54
Going Down	6.79	7.14	7.48

1.3 Why are they considered accurate

To ensure the accuracy of the measurements, the data was collected individually for each component to measure each step of the elevator data. This included the doors opening, idle time, door closing, going up and going down. Additionally, the data was considered for multiple floors of the elevator for additional data points. To ensure consistency, all the elevator idle times for the 7 floors were measured without anyone going in/out the elevator. Additional measurements for the idle time were conducted based on varying numbers of passengers entering or leaving the elevator. The time for going up and going down was measured to ensure the time was not impacted by gravity and the data for multiple floor travel times were collected.

2. Maximum Elevator speed and acceleration

To measure the acceleration we measured the time it takes for the elevator to travel multiple floors.

Table 3: Measuring the time it takes for the Canal elevator to travel multiple floors.

Floor Range	Going up (in seconds)	Going down (in seconds)
1 - 3	8.22	8.09
1 - 4	10.83	10.23
1 - 7	17.91	17.72

We also measured the number of steps between each floor of Canal building and the height of each step to estimate the distance between the floors:

- Number of steps between each floor of canal: 23
- Height of each step: 7.5 inches or 19.05 cm

Using the following assumptions:
- Assume acceleration rate = deceleration rate as per the assignment description.
- Assume the acceleration rate is constant

We can conclude that the elevator is accelerating for the first half of its trip and decelerating for the other half! The calculations are as follows:

Going up - acceleration

(Maximum acceleration occurred on floor two)
Total Distance: 2 * one floor or 8.76m
Time to go up 2 floors: 8.22s

Calculating one half: d = 8.76/2 = 4.38m, t = 8.22/2 = 4.11s, v1 = 0

$d = v_1 t + 1/2at^2$

$4.38 = 0 * 4.11 + 1/2a(4.11)^2$

$a = \frac{4.38*2}{(4.11)^2}$

$a = 0.519\, m/s^2$

$a_{net} = a_{elevator} - g \rightarrow a_{elevator} = 9.807 + 0.519 = 10.23\, m/s^2$

Maximum elevator acceleration when going up is: $0.519\, m/s^2$.

Going up - speed/velocity

(Maximum speed/velocity occurred on floor six)
Total Distance: 6 * one floor or 26.28m

Calculating one half, the distance is then 26.28m/2 or 13.14m
We know that $v_2^{\ 2} = v_1^{\ 2} + 2ad$

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$$v_2^{\ 2} = 0 + 2(0.336\, m/s^2)(13.14\, m)$$

$$v_2 = \sqrt{8.8301}$$

$$v_2 = 2.97\, m/s$$

Maximum elevator speed when going up is: $2.97\, m/s$

<u>Going down - acceleration</u>
(Maximum acceleration going down occurred on floor 2)
Total Distance: 2 * one floor or 8.76m
Time to go up 2 floors: 8.09s

Calculating one half: d = 8.76/2 = 4.38m, t = 8.09/2 = 4.045s, v1 = 0
$d = v_1 t + 1/2at^2 \rightarrow 4.38 = 0 * 4.045 + 1/2a(4.045)^2 \rightarrow a = \frac{4.38*2}{(4.045)^2} = 0.535\, m/s^2$
$a_{net} = a_{elevator} + g \rightarrow a_{elevator} = 0.535 - 9.807 = -9.272\, m/s^2$
Maximum elevator acceleration is when going down is: $0.535\, m/s^2$

<u>Going down - speed/velocity</u>
(Maximum speed/velocity occurred on floor six)

Total Distance: 6 * one floor or 26.28m
Calculating one half, the distance is then 26.28m/2 or 13.14m
We know that $v_2^{\ 2} = v_1^{\ 2} + 2ad$

$$v_2^{\ 2} = v_1^{\ 2} + 2ad$$

$$v_2^{\ 2} = 0 + 2(0.338\, m/s^2)(13.14\, m)$$

$$v_2 = \sqrt{8.8826}$$

$$v_2 = 2.98\, m/s$$

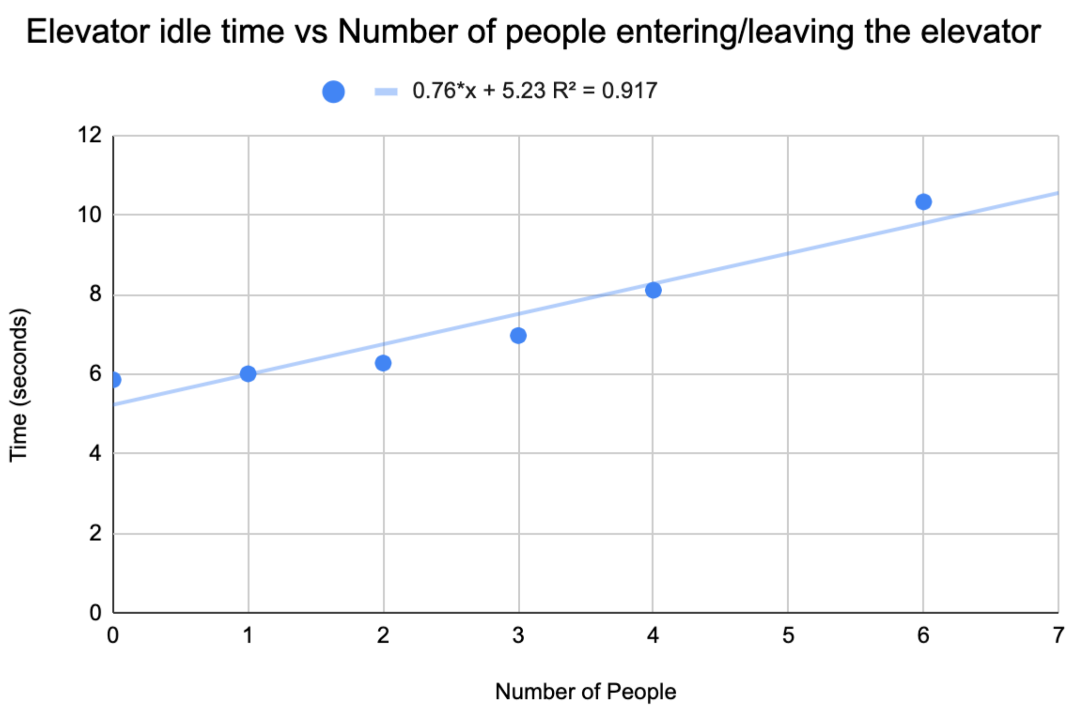
Maximum elevator speed when going down is: $2.98\, m/s$

3. Elevator Idle time based on

Table 4: Elevator idle time for different numbers of people entering/leaving the elevator.

Number of People Entering/Leaving	Elevator Idle (in seconds)
1	6.01
2	6.28
3	6.97
4	8.11
6	10.33

Figure 1: Measuring elevator idle time based on the number of people moving in/out



As shown in the graph this data can be represented by a linear function with 92% accuracy. The equation for the linear can be summarized as follows: $0.76x + 5.23$

This means that we expect the idle time for the elevator to increase based on the number of people moving in and out of the elevator.

All the previous measurements were conducted during the first time that the elevator doors were opened; meaning there was no interruption in the closing of the doors and addition of delays to accommodate for it.

To measure the extra delay added by the elevator after being interrupted another set of measurements were conducted. These measured the extra time added for the idle time of the elevator both right at the beginning and at the end of the doors closing.

Table 5: Elevator idle times when the door closing is interrupted by one person.

Time when closing doors were interrupted	Elevator Idle (in seconds)
Right when they were about to close	8.83
When they are almost fully closed	14.20

Using the above data we get the following new idle times:
Idle time after the elevator doors where interrupted right when they started closing: 8.83s
Idle time after the elevator doors where interrupted when they were almost closed: 14.20s

From the previous measurements we also know:
Average time for the doors to fully close: 4.02s
Average time for the doors to open: 2.19s
Average idle time for the elevator: 5.86s

We can represent the previous measurement as follows:
Extra delay for when the doors were about to close = measured idle time - avg idle time
8.83 - 5.86 = 2.97s extra delay was added

Extra delay for when the doors were almost closed = Measured time - doors closing - doors opening - avg idle time

14.20 - 4.02 - 2.19 - 5.86 = 2.13s extra delay was added

So the elevator adds between 2-3s of extra delay when its doors are interrupted!