Lab Report 1

Skyscaper

Nathan Warner

Northern Illinois
University

January 30, 2023

Contents

1 Theory

The objective of this report is to use unit conversion and estimation to find the number of people working in the Willis Tower and to find the water usage of the tower in liters per minute.

2 Data

Group #	Usable Area (m^2)	Workers	Water Usage (L/min)
1 (My Group)	970,000	80,000	21,000
2	1,500,000	100,000	25,000
3	2,000,000	180,000	45,000
4	1,200,000	80,000	20,000

Table 1: Final results from group rounded to two significant figures

3 Results

To estimate the number of usable area in the building, we first compute the first floor. If the dimensions are $450ft \times 450ft$, then the area is computed by

$$\begin{aligned}&(450ft)^2\\ =&202500ft^2.\end{aligned}$$

Examing figure 1, we deduce each subregion is given by

$$\frac{202500ft^2}{9} = 22500ft^2.$$

Takinng the square root gives

$$\sqrt{22500ft^2} = 150ft.$$

Thus, each subregion has the dimensions $150ft \times 150ft$. If we further split each subregion into a 5x5 grid, we get each square (around the perimeter) to be 30ft. With this calculation, we can get good estimations of the unusuable (white space). The calculations for unusable space per subregion is found in the following figure

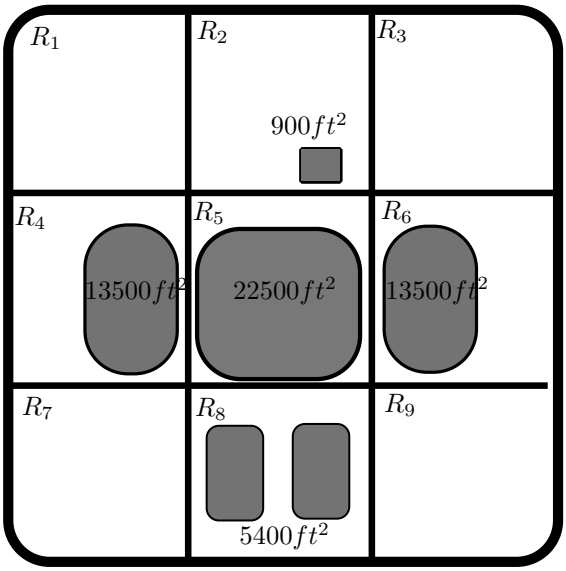

Figure 1

Next, we construct classes to represent which floors will have the same area. These findings are summarized in the following table

Floors	Subregions Available	Unusable area	Usable area
1-49	All	55800ft^2	$146700ft^2$
50-66	$R_1 - R_8$	$78300f^2$	$124200ft^2$
67-91	$R_4,\ R_5,\ R_6,\ R_9$	49500^2	40500^2
92-109	$R_5,\ R_6$	$3600ft^2$	$9000ft^2$

Thus, we have the usable area for the entire building

$$\begin{aligned}&49(146700ft^2) + 17(124200ft^2) + 25(40500ft^2) + 18(9000ft^2)\\ =&10474200ft^2.\end{aligned}$$

Converting to meters we get

$$\begin{aligned}&10474200ft^2 \cdot \left(\frac{12in}{1ft}\right)^2 \cdot \left(\frac{2.54cm}{1in}\right)^2 \cdot \left(\frac{1m}{100cm}\right)^2\\ =&973085.02m^2.\end{aligned}$$

Adjusting for two significant figures, we get the total usable area in the building as $970,000m^2$

Now that we have an estimation for the total usable area, we must estimate how much of this total usable space is actually occupied by cubicles. It may be reasonable to conclude that only $\frac{1}{3}$ of the total usable space is occupied by cubicles. This gives

$$\frac{970000m^2}{3} = 320000m^2.$$

We estimate each cubicle to be $\approx 2m \times 2m = 4m^2$. Thus, we have

$$\frac{320000m^2}{4m^2} = 80000 \text{ cubicles.}$$

If we deduce that each cubicle can house one person, we have approximately 80,000 workers in the building.

Next, we calculate the daily water usage

$$\begin{aligned} &80000 \text{ people} \cdot 100\text{gal} \\ =&8000000\text{gal/day.} \end{aligned}$$

Convering this to liters per minute we get

$$\begin{aligned} &\frac{8000000 \text{ gal}}{1 \text{ day}} \times \frac{3.7854 \text{ L}}{1 \text{ gal}} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{1 \text{ hour}}{60 \text{ min}} \\ =&21000 \text{ L/min.} \end{aligned}$$

4 Discussion

Upon reflecting on my report and comparing it with real-world data, it seems I might have been a bit off the mark. The claim from willistower.com about 15,000 people working in the Willis Tower daily makes my estimate of 80,000 workers seem way too high. Furthermore, this estimation also leads to an overestimation of the daily water consumption by the workers.

The dispersion displayed by the table of data is quite interesting. Although the dispersion is quite small, the variation between groups is quite noticable. I believe group four to have findings that are most resonable to real world data.

5 Conclusion

I found it rewarding to enhance my skills in unit conversion and estimation through this exercise. Although it was challenging at the beginning, everything eventually fell into place. In this scenario, we weren't testing a specific theory. It was interesting seeing what other groups were able to estimate. Perhaps more carefully considering how much usable space is actually occupied by cubicles may lead to a more reasonable estimation.

6 Colab Computation

6.1 Defined Constants

```
[28] from math import sqrt
```

```
floor_x = floor_y = 450 # Dimensions of a lower floor

in_per_ft: int = 12
cm_per_in: float = 2.54
cm_per_meter: int = 100
meter_per_cm: float = .01

liter_per_gal: float = 3.7854
day_per_hour: float = 1/24
hour_per_min: float = 1/60

cubicle_dimension: int = 2 * 2

num_subregions: int = 9

num_subregion_xsquares = num_subregion_xsquares = 5

# Number of tiles in each region with unusable space
unusable_subregion_tiles_r1 = 0
unusable_subregion_tiles_r2 = 1
unusable_subregion_tiles_r3 = 0
unusable_subregion_tiles_r4 = 15
unusable_subregion_tiles_r5 = 25
unusable_subregion_tiles_r6 = 15
unusable_subregion_tiles_r7 = 0
unusable_subregion_tiles_r8 = 6
unusable_subregion_tiles_r9 = 0

# Classes for identical floors
section1_floors = 49
section2_floors = 17
section3_floors = 25
section4_floors = 18
```

6.2 Computations

```
[85] floor_dimensions: float = floor_x * floor_y
     subregion_area: float = floor_dimensions / 9
     subregion_x = subregion_y = sqrt(subregion_area)
     area_subregion_tiles_x = area_subregion_tiles_y = subregion_x / 5

     unusable_space_r1 = unusable_subregion_tiles_r1 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r2 = unusable_subregion_tiles_r2 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r3 = unusable_subregion_tiles_r3 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r4 = unusable_subregion_tiles_r4 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r5 = unusable_subregion_tiles_r5 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r6 = unusable_subregion_tiles_r6 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r7 = unusable_subregion_tiles_r7 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r8 = unusable_subregion_tiles_r8 * (area_subregion_tiles_x * area_subregion_tiles_y)
     unusable_space_r9 = unusable_subregion_tiles_r9 * (area_subregion_tiles_x * area_subregion_tiles_y)

     usable_space_r1 = subregion_area - unusable_space_r1
     usable_space_r2 = subregion_area - unusable_space_r2
     usable_space_r3 = subregion_area - unusable_space_r3
     usable_space_r4 = subregion_area - unusable_space_r4
     usable_space_r5 = subregion_area - unusable_space_r5
     usable_space_r6 = subregion_area - unusable_space_r6
     usable_space_r7 = subregion_area - unusable_space_r7
     usable_space_r8 = subregion_area - unusable_space_r8
     usable_space_r9 = subregion_area - unusable_space_r9

     usable_space_list = [
         usable_space_r1, usable_space_r2, usable_space_r3,
         usable_space_r4, usable_space_r5, usable_space_r6,
         usable_space_r7, usable_space_r8, usable_space_r9,
     ]

     usable_space_section1 = 0
     for item in usable_space_list:
       usable_space_section1 += item

     usable_space_section2  = 0
     for i in range(8):
       usable_space_section2 += usable_space_list[i]

     usable_space_section3  = 0
     for i in range(3,6):
       usable_space_section3 += usable_space_list[i]
     usable_space_section3 += usable_space_r9

     usable_space_section4 = usable_space_r5 + usable_space_r6

     total_usable_space_ft = 49 *usable_space_section1 + 17 * usable_space_section2 + 25* usable_space_section3 + 18 *usable_space_section4
     total_usable_space_m = total_usable_space_ft * (in_per_ft**2) * (cm_per_in**2) * (meter_per_cm**2)

     space_used_by_cubicle = total_usable_space_m / 3
     num_cubicle = space_used_by_cubicle / cubicle_dimension

     num_workers = num_cubicle

     gallon_per_day = num_workers * 100

     liters_per_minute = gallon_per_day * liter_per_gal * day_per_hour * hour_per_min
```