Research questions and objectives

All parking lots on the OSU campus have been grouped into zones based on parking use patterns, and total permit sales in each zone are limited to improve parking availability (https://transportation.oregonstate.edu/parking/parking-guidelines). The price of an annual commuter permit varies by zone. In 2018, an A-zone permit (A1, A2, A3) costs $522; a B zone permit (B1, B2, B3) costs $351; and a C zone permit costs $108. A-zone permit holders may also park in the B and C zones, B-zone permit holders may also park in the C zone, and C-zone permit holders may not park in any other zones (Figure 1). Someone interested in buying an annual commuter permit may ask: is it worth it to pay for the more expensive permit?

In general, A and B zones are closer to the majority of buildings on campus compared to the C zone, which may allow the driver to get to class faster. This added convenience may make the extra cost worth it. However, if parking lots in the higher zones are likely to be full or nearly full, the diver may spend extra time driving around the parking lot searching for a parking spot, or may have to drive to another lot. In this case, the more expensive parking pass may not guarantee convenience, and the extra cost may not be worth it. On the other hand, higher zones may have lower average occupancy if higher zone permit holders are allowed to park in lower zones, but not vice versa. Furthermore, if occupancy rates are high in all three zones, a person may decide it is not worth it to buy a parking pass at all, and may opt for other transportation options.

Our objectives are to:

1) Estimate percent occupancy of parking lots within A, B, and C zones.
2) Determine whether significant differences exist in percent occupancy between zones.

If you purchased this permit:	You may park in these zones:
A1	A1, B1, B2, B3, C
A2	A2, B1, B2, B3, C
A3	A3, B1, B2, B3, C
B1	B1, C
B2	B2, C
B3	B3, C
C	C

Figure 1: Rules for parking between zones in the commuter parking zone. Due to these rules and the cost differential between parking permits in each zone, we predict parking lot occupancy will differ between zones.

Methods

Sampling Design and Sampling Frame

A stratified sampling design was used for this study. The three commuter parking zones (A, B and C) were used as strata. We thought this was a reasonable design given our objectives because it allows us to estimate percent occupancy for all commuter parking zones (using the stratified sampling estimate for population proportion) as well as produce estimates for each zone. Therefore, while our target population was all parking lots within the annual commuter permit zones (A, B, C) on the OSU campus, our sampled population was the randomly selected parking lots within each zone.

For our sampling frame, we made a list of all parking lots within zones A, B and C using a map of the parking lots obtained from Oregon State University transportation website (https://transportation.oregonstate.edu/parking/maps). We summed subzones A1, A2 and A3 to get a total of nineteen lots in Strata A, and summed subzones B1, B2 and B3 to get a total of 23 parking lots in Strata B. Zone C contained 5 lots, which included the parking lot around Reser Stadium, which was nearly 6 times larger than the next largest lot in all zones. We thought having vastly different lot sizes could bias the estimates of occupancy, so we split the Reser stadium lot into 6 subzones of roughly equal size, treating each zone as an independent lot. Therefore, we ended up with a total of 10 lots in Strata C. Total number of lots in all strata were 52.

Allocation method and selection of sampling units

Our allocation method was based on the following considerations: desired precision (preferably less than 10%); reducing spatial/temporal autocorrelation (i.e., we wanted to sample all lots at the same time on the same day); and budget constraints (we had 4 people available for sampling). Therefore, we decided that each person could reasonably sample two lots within a 45-minute period, and used a proportional allocation method based on strata size to select the number of lots to be sampled in each zone:

$$\frac{n_A}{N_A} = \frac{n_B}{N_B} = \frac{n_C}{N_C} = \frac{n}{N} = \frac{8}{52}$$

$$\frac{n_A}{19} = \frac{n_B}{23} = \frac{n_C}{10} = \frac{n}{N} = \frac{8}{52}$$

$$n_a = \frac{8}{52} \times 19 \ = 2.92 \ \approx 3$$

$$n_b = \frac{8}{52} \times 23 \ = 3.5 \ \approx 3$$

$$n_c = \frac{8}{52} \times 10 \ = 1.54 \ \approx 2$$

Lots were randomly selected in each zone according to the allocation method: 3 lots out of 19 were randomly selected in the A zones, 3 out of 23 in the B zones and 2 out of 10 in the C zones. Sampled lots are shown below in Figure 2.

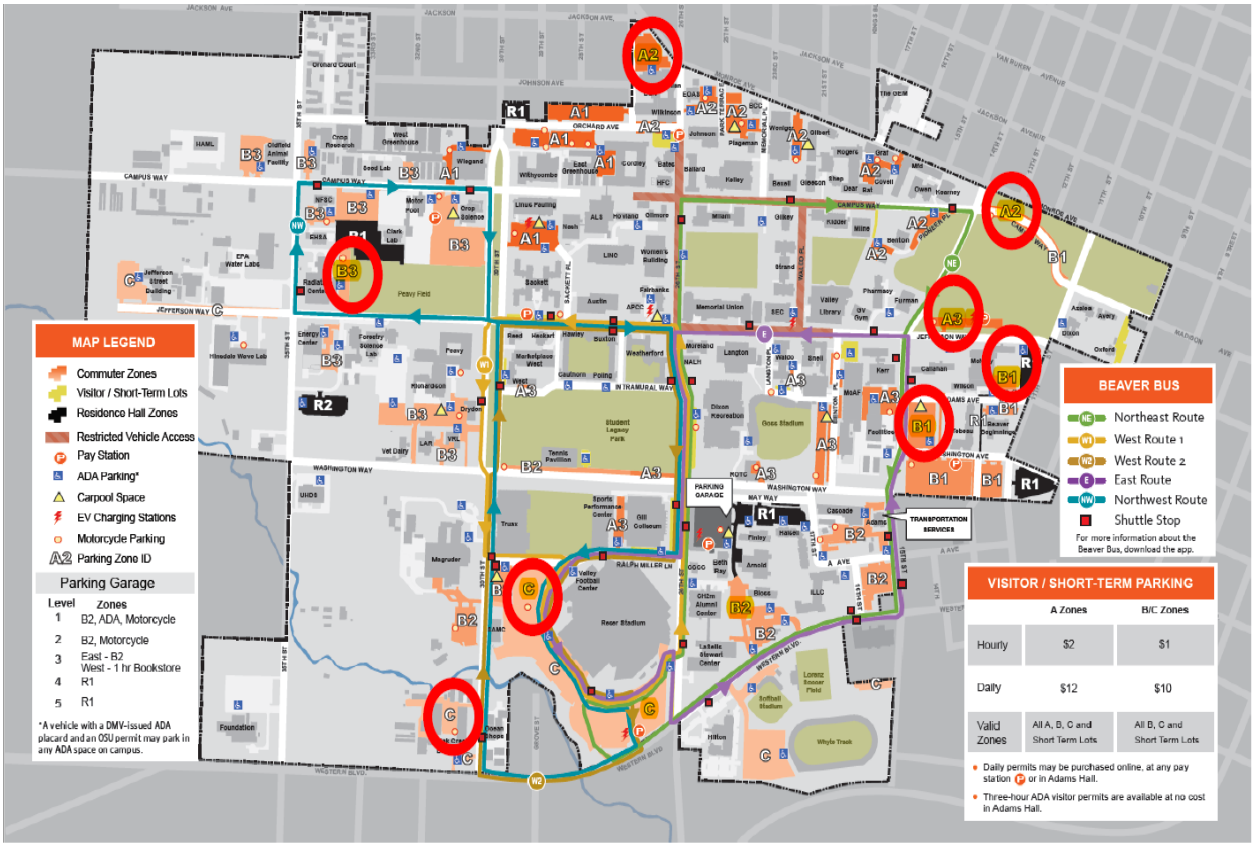

Figure 2: Our sampling frame was a list of all lots within commuter parking zones A, B, and C at OSU, which we made with this map of all parking lots at OSU. The red circles indicate the lots we randomly selected for our sample.

Sampling Protocol and Sampling Event

We conducted a pilot study of one parking lot on November 20, 2018 with all group members to determine a sampling protocol. We decided that each person should pretend they are searching for a parking space in an average-sized sedan and systematic walk down each row of the parking lot once, counting the number of occupied vs. unoccupied spaces on both sides of them. We defined a parking spot as any space that is large enough to fit an average-sized sedan that you would be allowed to park in with a commuter parking pass. This excludes any spaces within the lot that require a secondary parking pass (e.g., handicapped spaces, service vehicles), motorcycle spaces, loading zones, and any parking spaces that were occupied by permanent or semi-permanent objects (e.g., light poles, garbage cans, etc.). Since sampling a lot could take anywhere from 10-20 minutes, cars could come and go from the lot during the sampling period. We decided to ignore any cars that came and went behind us (in the area we already counted) and to account for any changes in front of us (in the area yet to be counted). For example, if a car

pulled into a spot in front of us that we have not yet counted, we would consider the space occupied, but if the car pulled in to a spot behind us that we already counted, we would not adjust our count.

Using the protocol described above, data was collected on Monday, November 26, 2018, between 12-12:45 p.m., with each person sampling 2 lots within the timeframe.

Results

After we sampled the eight lots, we collected the following data from three different zones.

	Sample 1		Sample 2		Sample 3	
Zone	Occupied	Total	Occupied	Total	Occupied	Total
A	27	28	54	88	48	87
B	32	52	20	22	189	206
C	134	180	52	63		

As the sampling design used was stratified sampling, we used estimated sample mean using the formula,

$$\bar{y}_{str} = \sum_{h=1}^{H} \frac{N_h}{N} \bar{y}_h$$

And its standard error using the formula,

$$SE(\bar{y}_{str}) = \sqrt{\sum_{h=1}^{H} \left(1 - \frac{n_h}{N_h}\right) \left(\frac{N_h}{N}\right)^2 \frac{s_h^2}{n_h}}$$

We estimated occupancy rate as 77% with 6% standard error. This led to the conclusion that OSU parking lots are occupied 77% of its full capacity at noon on Mondays. We plotted these individual proportions using boxplot to check the occupancy rate in three different zones. Figure 3 shows the boxplot of occupancy rates.

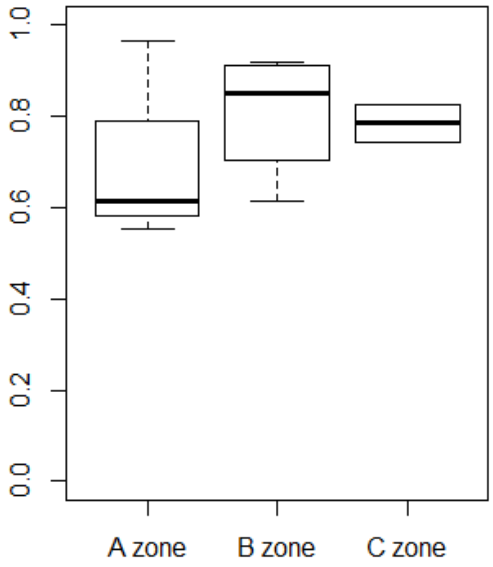

Figure 3: Boxplot of observed percent occupancy of lots in three zones.

We made three observations from the above boxplot. i) None of the zones have 100% occupancy rate at noon time. ii) Variation is the highest in zone A, moderate in zone B and least in zone C. iii) All the three zones have almost close occupancy rate close to 80%.

Conclusions

We made the following conclusions from our study. First, as none of the zones have full occupancy, one should be able to find parking in A, B, or C lots reliably on Mondays at noon without having to drive between multiple lots. Second, as all three zones' occupancy is very close to each other, occupancy rate does not seem to be significantly different between zones (though the estimate for C was lower than A and B). Therefore, one should select a commuter parking pass based on your budget and desire for proximity to buildings, and not be concerned with differences in occupancy between zones.

The limitation of our study is we had a narrow scope of inference that may not be reasonably generalized to other days and times. We sampled only once at noon on a Monday after Thanksgiving break. Since there is a possibility that not students had returned from the break, the occupancy rate might not be representative of all Mondays. Furthermore, parking varies from Monday to Tuesday as classes are on either MWF schedule or TR schedule. Hence at best, we can stretch our conclusion only to MWF. Finally, parking occupancy likely varies by time within a single day. We collected our data during the lunchtime hour, and people may have left campus to get lunch. Therefore, our study may underestimate occupancy rates of the lots. Nevertheless, we can say with our data that on Monday after Thanksgiving break at noon, you should be able to find a parking spot in any commuter parking zone at OSU.