USC Parking Expansion Project

[redacted]

Problem Statement

For years, USC has received complaints from students about parking availability on campus. To respond, the USC Board of Trustees has decided to conduct a study into which parking lot should be expanded. They decide to survey 5 different groups to determine which factors stakeholders value most in parking lots. They ask a randomized group of 25 undergraduate students (non-athletes), graduate students, athletes, professors, and senior academic administrators which factors they value most. The variables that appeared most important to the various groups were the distance from the center of campus (D), number of entrances (N), whether the lot has charging piles (CP), the number of available parking spaces at a given time (A), and the crimes in the immediate area (C). The university identifies 8 lots with the potential of being expanded, listed below (see the map in appendix I):

McCarthy (M), Downey (D), Jefferson (J), Royal (R),
Shrine (S), Flower (FL), Figueroa (FI), Grand (G)

Given the above information, find A) the master scaling constant, B) the final rankings for the various groups, C) the concordance between the different groups, D) the final rankings between all of the groups, and E) a decision tree showing the benefits of adding spaces, assuming that the most desirable lot is the most likely lot to be expanded.

Assumptions

For the purposes of this project, we assume that nominal pre-COVID usage rates are expected for the various parking lots, meaning that in-person classes are in session and traffic rates are about average. We're also assuming that each lot has the ability to be expanded. This could mean having additional floors, extending underground, or using space currently allocated to other buildings or public space. We also assume that USC is gathering information about utilities for each lot without accounting for different costs or building codes. Finally, a few assumptions are required to model the availability of the lots. For this project, we're examining the availability within the lots at 5pm to get a rough estimate of overall usage for other times. We assume that the relative availability of each lot is roughly constant, meaning that lots that are comparatively busy at 5:00pm are also comparatively busier than the other lots at other times.

Methodology

For each of the criteria in the problem statement, the University needs to quantify and normalize the data on each of the lots. The number of entrances (N) and distance to the center of campus (D) are straightforward and objective, so the numbers (in number of entrances and miles, respectively) are tracked below. A boolean value is used for whether Charging Piles are found at the lot (CP), meaning that a value of 1 is shown if there are charging piles and 0 will be used if there isn't. Availability is harder to quantify, so the group took a simulated sample of each of the lots at 5pm on various days to develop a range of available spots.

The crime rates of the various parking lots are also difficult to accurately predict because most statistics don't have granularity into the specific regions where crimes likely occur. The annual USC security Fire and Safety report indicates that there were 139 sexual crimes and 31 other violent on campus (USC Annual Report, 2019, pg 93), so we simulated an uneven split for the 170 crimes across the various lots. Counting all 170 is warranted here, because the area defined as "on-campus" on page 92 is geographically close to every lot. The total crime out of 170 (based on 2019) in each area is shown in the table below.

The data table for the 8 alternative parking lots and 5 attributes is shown below.

Parking Lot	Entrance, N (# of Entrances)	Distance, D (Miles)	Charging Pile, CP	Availability, A (Range at 5pm)	Crime, C (Annual Crimes)
M	1	0.40	0	10	25
D	2	0.20	1	12	16
J	2	0.50	0	15	24
R	2	0.30	1	10	20
S	[illegible]	0.80	1	20	25
FL	2	0.43	0	30	21
FI	3	0.47	1	25	20
G	1	0.66	1	30	19

After gathering the information through surveys (see Appendix I), we came up with the following attribute utility functions that best represent the preference of those stakeholders. The utility attribute functions are normalized based on the values in the table above, and use exponents and roots to shift the utility growth to the left or right in each function.

U(N) = $1/4 * (N-1)^2$, $1 \leq N \leq 3$
U(D) = $25/9 * (D-4/5)^2$, $0.2 \leq D \leq 0.8$
U(CP) = CP, $0 \leq CP \leq 1$
U(A) = $1/\sqrt{20} * \sqrt{A-10}$, $10 \leq A \leq 30$
U(C) = $1/3 * \sqrt{25-C}$, $16 \leq C \leq 25$

The survey results also led to the tradeoff scaling constants below. After separating out the various categories of responses between the different stakeholders, a few trends emerged. First, the groups largely prioritize distance, availability, and safety over the other factors. The faculty is more likely to be wealthy and own electric vehicles, while athletes are better able to deal with distance and are less likely to be targets of petty crimes than other students. Punctuality, and thus availability, appeared to be more important for athletes and staff than for students who have more flexible schedules. The tradeoff scaling constants reflect these findings and show the comparative importance placed onto each factor for the different groups.

For undergraduate students:

k_N=0.35 k_D=0.6 k_{CP}=0.1 k_A= 0.4 k_C=0.6

For graduate students:

k_N=0.2 k_D=0.5 k_{CP}=0.2 k_A= 0.3 k_C=0.4

For professors:

k_N=0.3 k_D=0.5 k_{CP}=0.3 k_A= 0.5 k_C=0.4

For senior academic administrators:

k_N=0.25 k_D=0.4 k_{CP}=0.3 k_A= 0.5 k_C=0.3

For athletes:

k_N= 0.15 k_D=0.2 k_{CP}=0.1 k_A= 0.6 k_C=0.2

Analysis and Calculations:

Using the above tradeoff scaling constants, we used the equation $1+K=\prod_{n=1}^{N}[1+K\cdot k_n]$ to calculate the master scaling constant of each group. We used this value to find MAU and rankings.

For undergraduate students: K= -0.922755

Parking lots	M	D	J	R	S	FL	FI	G
Multiattribute Utility	0.267	0.925	0.513	0.757	0.357	0.771	0.862	0.754
Ranking	8	1	6	4	7	3	2	5

For graduate students: K = -0.760955

Parking lots	M	D	J	R	S	FL	FI	G
Multiattribute Utility	0.222	0.886	0.404	0.704	0.380	0.649	0.796	0.681
Ranking	8	1	6	3	7	5	2	4

For professors: K = -0.895206

Parking lots	M	D	J	R	S	FL	FI	G
Multiattribute Utility	0.222	0.885	0.484	0.732	0.559	0.753	0.885	0.805
Ranking	8	2	7	5	6	4	1	3

For senior academic administrators: K = -0.821478

Parking lots	M	D	J	R	S	FL	FI	G
Multiattribute Utility	0.178	0.834	0.444	0.669	0.566	0.720	0.872	0.793
Ranking	8	2	7	5	6	4	1	3

For athletes: K = -0.5079

Parking lots	M	D	J	R	S	FL	FI	G
Multiattribute Utility	0.089	0.632	0.427	0.394	0.503	0.765	0.830	0.784
Ranking	8	4	6	7	5	3	1	2

Concordance:

Using the below formulas, we can calculate W and $S_{critical}$.

Kendall's Coefficient of Concordance

$$W = \frac{S}{\frac{1}{12}k^2(N^3 - N) - k\sum_{i=1}^{k} T_i}$$

where

$$S = \sum_{j=1}^{N}(R_j - \bar{R})^2$$

$$\bar{R} = \frac{1}{N}\sum_{j=1}^{N} R_j = \frac{k(N+1)}{2}$$

N = number of alternatives
k = number of decision makers
R_j = Sum of the ranks assigned to alternative j
t_{ij} = Number of tied observations for rank j and DM i

$$T_i = \frac{1}{12}\sum_{i=1}^{N}(t_{ij}^3 - t_{ij})$$

W=0.86667

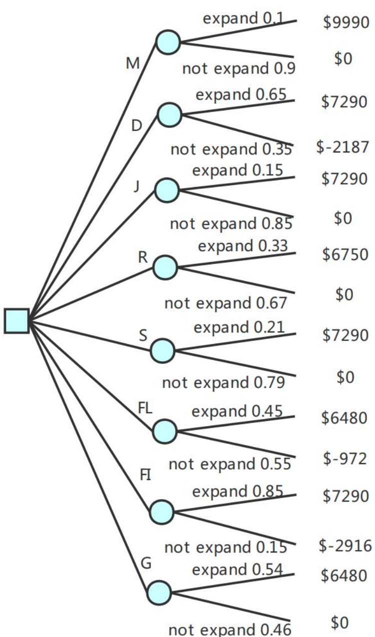
$S_{critical}$(m=5, N=8)=183.7

Because $S_{critical}$ is less than S, we conclude that the rankings are in agreement at 5% level of significance. We then find the Nash and Additive Rankings by taking the product and average of the various multiattribute utilities, respectively. For Borda, we simply sum the preference order of the 5 different groups. The order after doing this of each method is shown below:

Nash, Borda, and Additive Utility :

Parking lots	M	D	J	R	S	FL	FI	G
Nash Ranking	8	2	7	5	6	4	1	3
Borda Ranking	8	2	7	5	6	4	1	3
Additive Ranking	8	2	7	5	6	4	1	3

Similarly, we use the formulas above to find the ranking concordance of three different rules. We have W = 1 which tells us the rankings are in perfect agreement at 5% level of significance.



After finding out the rankings based on the preference of different groups, we can consider the increased payoffs of each parking lot after the expansion within a semester to help USC make the final decision. We assume that after we expand one parking lot, this parking lot can have 20 more parking spaces. So the increased payoff is 20 times the rate of a semester. For example, if the USC decides to expand the McCarthy(M), the increased payoff should be 20*$499.9 which is $9990. If USC doesn't expand some popular parking lots with many cars, some people may not be willing to choose them, which will reduce the payoffs of these parking lots. The probability of each parking lot being expanded in the decision tree is based on the rankings we calculated above. The popular parking lots are more likely to be expanded.

After calculation, Figueroa has the highest expected value $5759.1. This result is consistent with the expectations of different groups and will also bring a certain amount of financial income to the school.

Figure 1 Decision Tree

Conclusions

From the analysis above, the university should expand the Figueroa (FI) lot if they want to maximize utility, followed by the Downey (D) lot. These lots both have multiple entrances and charging piles. Figueroa also has high availability, while Downey is very close to the center of campus with a very low crime rate. The preferences of both the undergraduate and graduate students match up closely, while the preferences of both the faculty and the senior academic administrators also match closely. Despite the different values that the stakeholders place on these attributes, these decisions do show concordance among the various groups.

In this report, for convenience of computation and analysis, we have made some assumptions. We didn't consider the cost of expanding the parking lots, the available space to be expanded, and the availability of parking spots at other time periods. But in real life, we need to consider more factors if we want to help the USC Board of Trustees to make the right decisions.

References:

Charging Pile Location. (n.d.). Retrieved November 24, 2020, from https://na.chargepoint.com/charge_point

USC. (2020, October 15). Annual Security and Fire Safety Report 2019. Retrieved from https://dps.usc.edu/files/2020/10/Updated-ASR-2019-10.13.2020-MW-Final.pdf

USC. (2020). University Park Campus. Retrieved from https://web-app.usc.edu/maps/map.pdf

Appendix I

Figure 1 The map of parking lots

Appendix II

Link of the Survey:

https://docs.google.com/forms/d/e/1FAIpQLScHsMur0p-sIFA5HtHmemQuQUafR6M_r8v30fCs_x2pU_tLyQ/viewform?usp=sf_link

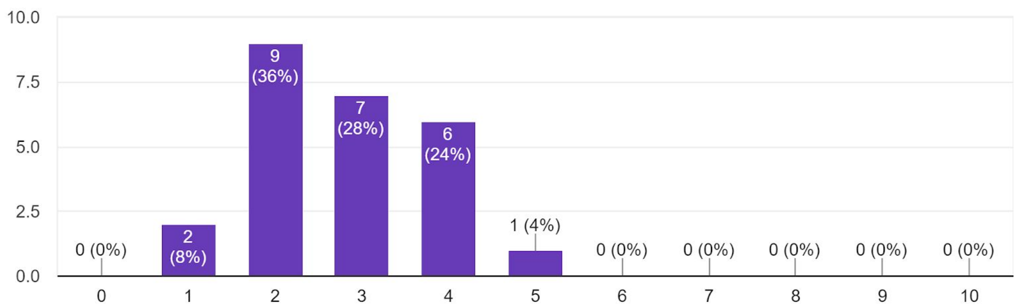
Summary of the survey:

The axis of x means the scale of importance. 0 represents not important at all and 10 represents extremely important.

The axis of y means the number of respondents that choose the corresponding scale.

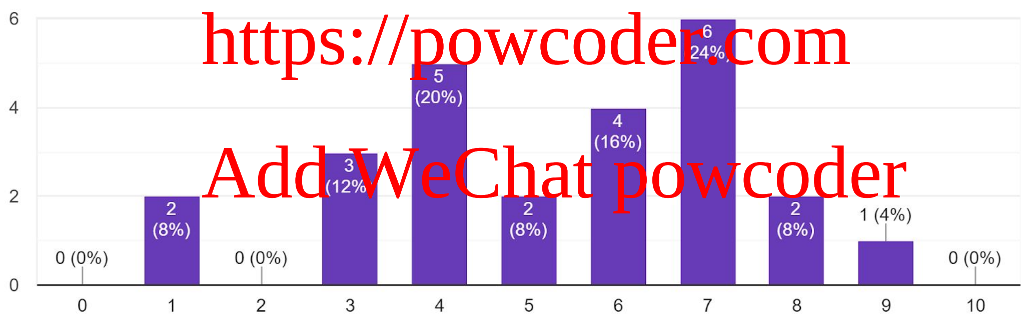
How important is the number of entrance to you?

25 responses



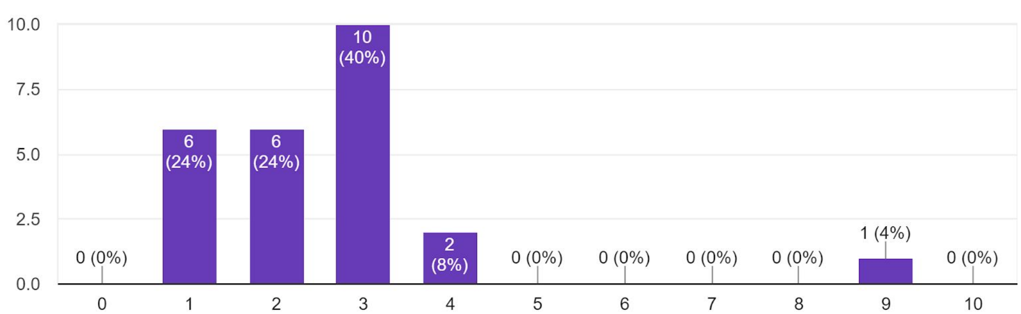
How important is the distance between your parking lot and Campus Center to you?

25 responses



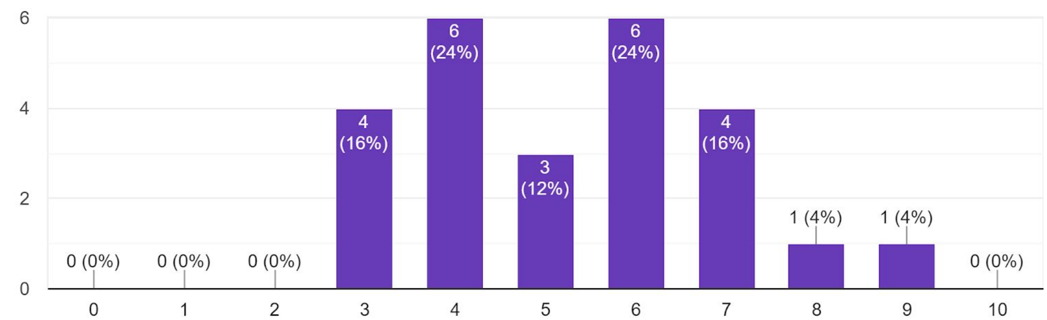
How important is a charging pile you?

25 responses



How important is the availability of finding a parking spot to you?

25 responses



How important is the crime around the parking area to you?

25 responses