Traffic Congestion at UCSC

CSE 174

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Introduction

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UCSC has a population of about 20,000 students and staff going on campus everyday, 9000 of them live on campus and only have two roads access it. The future enrollment forecast estimates that there will be an additional 1000 students every year for the next 10 years. As off-campus students, we have experienced the effects of traffic congestion on campus that affect everybody, especially at peak hours. Our project will deal with this major issue and we will try to provide the best solution by applying all the concepts of decision analysis.

Background

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According to TAPS, 75% of traffic on campus is single occupancy cars when buses only account for 5% of it and carry respectively 35% and 37% of the total passenger on campus. Buses are clearly the most efficient way of transportation on campus in view of the global context and that's why our analysis will focus on buses and its efficiency. We dealt with three following options: the first one is to add more loops at peak hours, the second one deals with introducing a priority card and the last one tackles a selective bus stop, all of them being described later on.

Uncertainties remain mostly in the behaviors of all the parties involved (students, staff, UCSC, Metro Center) to adopt a new solution. Thinking about tradeoffs we can think about the costs for all parties or the satisfaction because for some solutions on-campus students will be affected.

Alternatives Explored

Alternative 1 - More Loops

Colin McKinnon
Samuel Derlot

When traveling around the UCSC campus, the fastest way to get from one place to another is to ride one of the UCSC buses, called a Loop. Oftentimes during peak hours, there are not enough Loop buses for students to take. Therefore, students are forced to just take the first bus that they see, sometimes a Santa Cruz Metro bus. Having students on city buses just to travel around campus means that students who wish to go off campus often have to wait a long time for an open city bus to take. Because of this, most students opt to drive to campus everyday because it is more reliable, even though it creates more traffic congestion.

Taking this into consideration, we believe our alternative of adding more loops during peak hours will help to solve this problem. This is because students will be able to easily board Loops buses to travel around campus, freeing up space for students who really need a city bus to get off campus. In making the city buses more reliable, more students will opt to take buses to campus instead of driving, decreasing traffic.

Alternative 2 - Premium Cards or Priority Cards

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Ashwin Chidambaram

Perhaps the main reason why students drive to campus, increasing traffic congestion, as opposed to taking the Santa Cruz Metro buses is due to crowded buses that are constantly too full to pick up all passengers at a given stop. This unreliable system forces most students to drive so that they can efficiently travel to and from campus without wasting time.

In order to ensure off-campus students can rely on the bus system, our group decided that giving them priority over on-campus students could help. To do this, we decided that a student could indicate they are off-campus in one of two possible ways. The first is by purchasing a premium card through UCSC, which would allow them to board the city buses before on-campus students. Similarly, the other way off-campus students can gain priority would be by obtaining free priority cards which would be subsidized by UCSC, allowing them to board city buses first. Ensuring that off-campus students board buses first, means that students would be able to rely more on the bus system so that they would not need to drive to campus. More students taking buses means less cars on campus and reduced traffic congestion.

Alternative 3 - Selective Bus Stops

Ashwin Chidambaram
Colin McKinnon

On the UCSC campus, there are a few bus stops that are generally very busy with people getting both on and off the buses . The ones that we determine to have the highest rates of traffic would be Cowell/Bookstore, College Nine/Health Center, Science Hill, and the Porter/RCC stops. We believe that by establishing “selective” bus stops on campus where a metro bus will only selectively make stops might allow commuters to make it home easier while also enabling students on campus to traverse campus without too much of a hassle.

Based on what we observed with students on campus in addition to our own experiences, students tend to opt for the bus even if it is simply to just get to the next bus stop, despite it being faster to walk there in comparison to waiting, boarding, and riding the bus. We can conclude that students will generally tend to choose the option which they perceive as easier and requires less effort. Seeing as this is the case, we would need to ensure that the bus stops are not adjacent to ensure that students are disincentivized to ride the bus to get around within campus.

Taking these factors into account: We propose having these selective stops be located at Base of Campus, Cowell/Bookstore Busstop, Science Hill Busstop, and Porter/RCC Busstop.

Method

Fundamental Objectives Hierarchy

Colin McKinnon
Ashwin Chidambaram

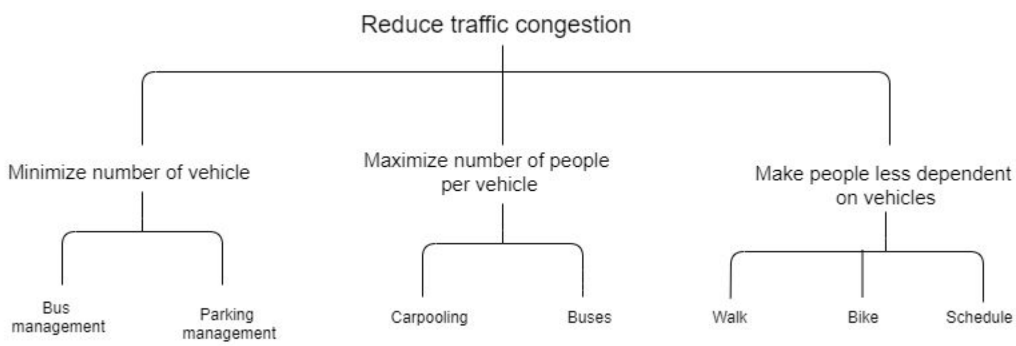

Figure 1: Fundamental Objective Hierarchy for UCSC Traffic Congestion Problem

Through our fundamental objectives hierarchy, shown in *Figure 1*, we are able to identify the fundamental objective in our project, to reduce traffic congestion at UCSC. Under the fundamental objective, we identify mean objectives that tell how traffic congestion can be reduced. Branching off of each of those mean objectives, we show examples of fulfilling those specific mean objectives. Overall, *Figure 1* allows us to display what we mean by how we will achieve our fundamental objective, to reduce traffic congestion.

Means Objective Network

Colin McKinnon
Samuel Derlot

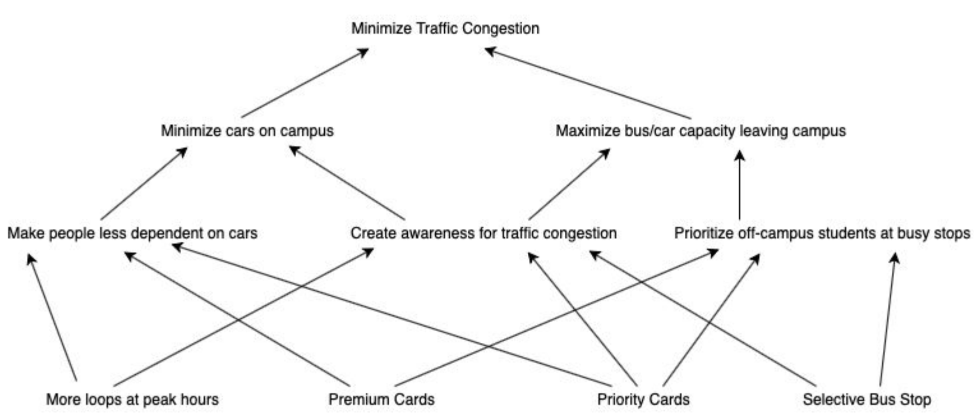

Figure 2: Mean Objective Network for UCSC Traffic Congestion Problem

In the means objective network, *Figure 2* above, we clearly identify our alternatives at the bottom of the network. From these alternatives, we are able to branch up to some of our means objectives, which help to show why each alternative is significant in achieving the fundamental objective. The first initial row of mean objectives branch up to what we identify to be two overarching mean objectives. We chose minimizing cars on campus and maximizing the bus and car capacity leaving campus to be the two main mean objectives because they are the two main ways that we will be able to achieve our fundamental objective. Through *Figure 2,* we are able to see how each alternative is going to allow the fundamental objective to be achieved.

Influence Diagram

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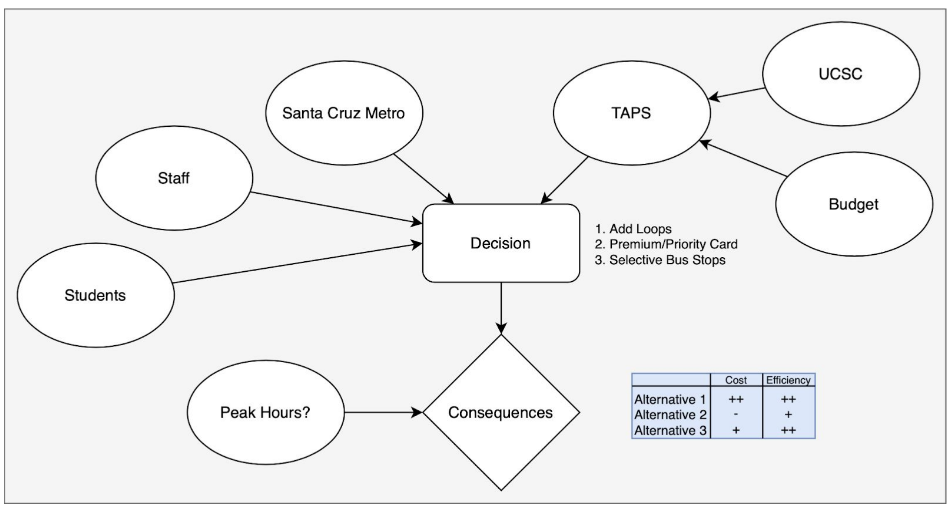

Figure 3: influence diagram for UCSC traffic congestion problem

In the influence diagram we can distinguish the decision, the consequence and the chance nodes that represent all the parties involved in the decision and the uncertainties. We chose to differentiate the consequences of each alternatives according to their cost but also to their efficiency.

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Decision Tree

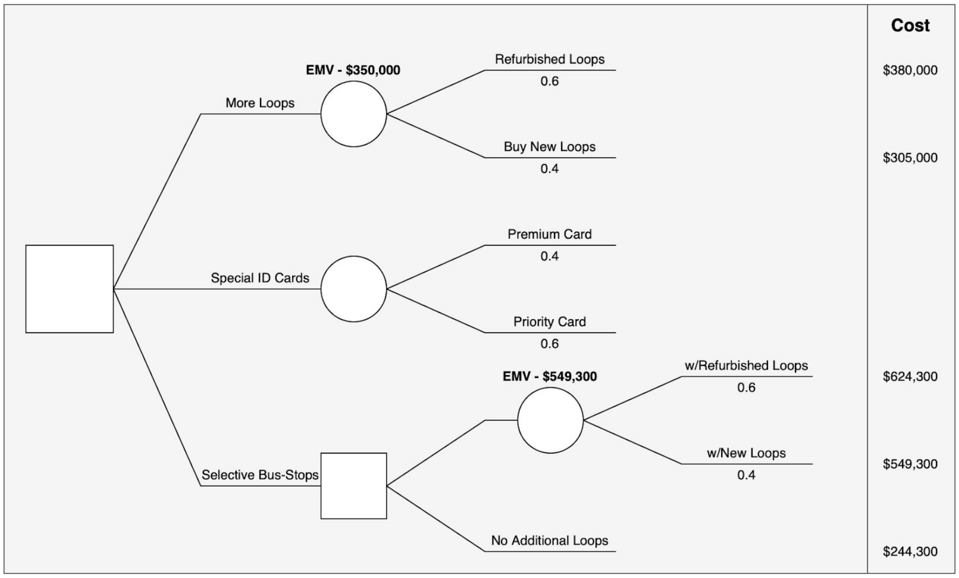

Figure 4: Decision Tree for Mitigating Traffic Congestion at UCSC

For our decision tree, we decided to narrow down our original four alternatives into three instead seeing that the differences between premium and priority cards were marginal. Additionally, we faced the issue of not being able to determine the probability for each alternatives acceptance by UCSC. To be able to do this, we performed a survey and sent it out to a mix of college students through our connections to gauge their interest and opinion on each of the alternatives. Above, in our first branch of the decision tree, we can see this probability represented for each alternative. However, we faced an additional issue of how to deal with the probability of the secondary branches in the decision tree, seeing as we still wouldn't have access to decision making data made by UCSC. To mitigate this, we assigned one of three probability values: 0.2, 0.3, or 0.5. Where 0.5 would represent the least costly option, and thus more likely to be adopted by UCSC; 0.2 would represent the most costly option, and the least likely to be adopted; and 0.3 which would represent a monetary value that is within reason and neither the most or least expensive option. While this does introduce a significant amount of bias due to the nature of our survey as well as our somewhat arbitrary method of assigning probability, this is the best that we were able to achieve with the data and knowledge we possess.

Data Sources

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For our data sources, we acquired data from TAPS on vehicular traffic through campus and data taken from both UCSC Loops and Santa Cruz Metros. However, due to the time frame in which we finally received the data, we were unable to perform lots of analysis on it considering in total we had over 1,000,000 data points. However, for the sake of analyzing the data, we opted to focus mainly on the metro ridership data and use that to draw some basic conclusions. If we had more time, we would take into account all of the data we have and use that to draw more accurate conclusions.

The data we collected from TAPS was also not very cleaned up due to the massive amount they gave us, so we had to clean the dataset ourselves. To do this, we wrote a custom Python script [csvmodifier.py][1] which was used to take a dataset with 990,722 data points, and cleaned to make it possible to import into pgAdmin. In pgAdmin, we created a new table in which we store all the data, and the reason for this was to be able to quickly pull any relevant information since it allows us to process lots of data in a relatively short amount of time.

[1] https://github.com/ashwinchidambaram/PythonCode/blob/master/CSE-174/csvmodifer.py

Data

Analysis of Added Loop Buses

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For this first alternative, we were tasked with figuring out the yearly cost for new articulated buses and for renting articulated buses. In order to do so, we begin by figuring out when the peak times are for adding more loops. After looking through information given to us by TAPS at UC Santa Cruz and through their UCSC website, we found that the peak times to add loops would be from 3:30 PM to 5:30 PM. Given that this is a busy time, we thought that having two loops, one going in each direction around campus, every 20 minutes would maximize efficiency without adding to the traffic congestion. Using this, and the given information form TAPS that Loop buses take, on average, about 30 minutes to get around campus during peak times, we found that a total of 4 drivers are needed. In the calculations below, you can see how we used all of this information to find the time worked for each group of drivers, 1 hour and 50 minutes for the first group of drivers and 1 hour and 40 minutes for the second group of drivers. When you multiply each of these by 24, to account for hourly driver wage times number of drivers, you find the daily cost for all of the drivers. In addition to this, we show below how we used given information from TAPS about gas capacity, the average price of gas in Santa Cruz, and the amount of buses needed in order to figure out the daily cost of running a bus that starts with a full tank. When you add the daily costs of drivers to the daily costs of the buses, you find that the total daily cost of our proposed solution is $1200/day.

Driver Group 1= 3:30-4:00	Driver Group 1= 4:10-4:40	Driver Group 1= 4:50-5:20	Time for Driver Group 1= 1 hour and 50 minutes
Driver Group 2= 3:50-4:20	Driver Group 2= 4:30-5:00	Driver Group 2= 5:10-5:30	Time for Driver Group 2= 1 hour and 40 minutes

$$cost\ to\ run\ buses\ \ per\ day\ = [((T1)(\frac{Driver\ Salary}{hour}) + (T2)(\frac{Driver\ Salary}{hour}))(\frac{\#\ of\ buses}{time\ of\ day}) + (\frac{fuel\ capacity}{bus})(\frac{fuel\ cost}{gallon})(\frac{\#\ of\ buses}{day})]$$
$$= [((1.83hr)(\frac{\$12}{hr}) + (1.66)(\frac{\$12}{hr}))(\frac{2\ buses}{time\ of\ day}) + (\frac{\$279}{bus})(\frac{4}{day})]$$
$$= [(\$22 + \$20)(2) + \$1116$$
$$= \$1200/day$$

Knowing the daily costs of this solution, we were then able to find the yearly cost for new articulated buses. We did this by figuring out that there are going to be 150 days in a given year where the peak times would need to be accounted for. Multiplying this by the daily costs gives the total everyday costs in a given year. In order to take into account the costs of a new articulated bus, we researched and found the cost of a new articulated bus to be $305,000. In order to have that in terms of yearly cost, we divided that by the total lifespan of a new bus, 12 years. We multiplied this by 4 buses because that is the total amount of buses needed for this alternative. The number we get from this represents the yearly cost of new articulated buses. Below you see that we added this to the total everyday costs in a given year in order to find out the yearly cost for new articulated buses to be $305,00 per year.

$$yearly\ costs\ =\ (\#\ of\ days\ running)\ *\ (cost\ to\ run\ buses\ \ per\ day)\ +\ (cost\ of\ new\ buses\ )$$

$$\#\ of\ days\ running =\ [(\frac{3\ quarters}{school\ year})(\frac{10\ weeks}{quarter})(\frac{5\ days}{week})]$$
$$= 150\ days/school\ year$$

$$Total\ everyday\ costs\ in\ a\ year\ =\ (\#\ of\ days\ running)\ *\ (cost\ to\ run\ buses\ \ per\ day)$$
$$= (\frac{150\ days}{school\ year})(\frac{\$1200}{day})$$
$$= \$180000\ days/school\ year$$

$$cost\ of\ new\ buses\ \ = [\frac{cost\ of\ new\ bus}{avg.\ lifetime\ of\ bus} * \#\ of\ buses\ ]$$
$$= \frac{\$375000}{12\ years} * 4\ buses$$
$$= \$125000/year$$

$$yearly\ cost\ for\ new\ articulated\ buses = (\frac{150\ days}{school\ year} * \frac{\$1200}{day}) + \frac{\$125000}{year}$$
$$= \frac{\$180000}{school\ year} + \frac{\$125000}{year}$$
$$= \$305000/year$$

The second yearly cost needed for this alternative is the yearly cost to lease buses. Because we already know how to find the total everyday costs in a given year from above, we are left with just finding the yearly cost of leasing buses. To do so, we researched that the cost of renting articulated buses in Santa Cruz is $5000 per month. When we multiply this by 10 months, to account for the months in which school is in session, and by 4 buses, to account for the total amount of buses needed for this alternative, we get the number representing the yearly cost just for renting articulated buses. Adding this to the total everyday costs, shown below, gave us the total yearly cost incurred by Santa Cruz if it were to lease more loop buses: $380,000 per year.

$$yearly\ costs\ =\ (\#\ of\ days\ running)\ *\ (cost\ to\ run\ buses\ \ per\ day)\ +\ (cost\ of\ leased\ buses\ )$$

$$\begin{aligned} cost\ of\ leased\ buses\ &= [\tfrac{cost\ of\ bus}{month}\ *\ \tfrac{months}{year} * \#\ of\ buses\ ] \\ &= \tfrac{\$5000}{month} * \tfrac{10\ months}{year} * 4\ buses \\ &= \$200000/year \end{aligned}$$

$$\begin{aligned} yearly\ cost\ for\ leased\ articulated\ buses &= (\tfrac{150\ days}{school\ year} * \tfrac{\$1200}{day}) + \tfrac{\$125000}{year} \\ &= \tfrac{\$180000}{school\ year} + \tfrac{\$200000}{year} \\ &= \$380000/year \end{aligned}$$

Analysis of Priority Cards

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This option that we can tackle as two: a premium and a priority card. Data[1] show that half of the student population lives on campus and can therefore take the loop to move around campus, it also means that 10,000 students living off campus depend on the Metro buses to commute to campus. With the first solution, students living off-campus would have the choice to pay a fee of $25 (price of student card) that would be unique and allow priority on Metro buses. We estimated that between 1,000 and 7,000 students would buy the card with a most likely value of 4,000. This estimation implies that Metro buses would earn a medium value of $100,00 ranging between $25,000 and $175,000. This money could be used to train bus drivers on how to react and tackle the problem with uncooperative students. But the surveys done as part of the project showed that students are more in favor of the other solution: add a priority sticker or other method of identification to existing ID cards. Indeed the sticker cost would be very low for UCSC, around

$0.05/sticker so even if all off-campus students ask for it, the total cost would be about $500 but the efficiency can be put into question.

However, this solution can hardly be compared to the two others because its efficiency can not be evaluated.

Analysis of Selective Bus Stops on Campus

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For Alternative 3, we are considering the idea of a metro bus stopping only at designated bus stops on campus. Our goal in this analysis, is to compare three potential scenarios within the Selective Bus Stop alternative. We can opt to utilize selective bus stops in tandem with an increase in the number of new loop buses on campus, or with the addition of leased loop buses on campus, or simply implementing only selective bus stops. We shall compare the overall costs and savings of each alternative and determine the most cost effective alternative.

To understand the cost of running a bus with only selective bus stops, we need to first determine the cost of running an articulated metro bus per year. This calculation will be done roughly since we are not taking into account all factors, however we are assuming that the Santa Cruz metro can't spare any articulated buses , and will need to purchase two new ones. Additionally, we are estimating the EMV over a course of 12 years, since that is the average lifetime of a new bus.

Selective Bus Stops [ONLY]

$$yearly\ costs\ =\ (\#\ of\ days\ running)\ *\ (cost\ to\ run\ buses\ \ per\ day)\ +\ (cost\ of\ new\ buses\ )$$

$$\#\ of\ days\ running = \ [(\frac{3\ quarters}{school\ year})(\frac{10\ weeks}{quarter})(\frac{5\ days}{week})]$$
$$= 150\ days/school\ year$$

$$cost\ to\ run\ buses\ \ per\ day\ \ = [((Peak)(\frac{Driver\ Salary}{hour}) + (NotPeak)(\frac{Driver\ Salary}{hour}))(\frac{\#\ of\ buses}{time\ of\ day}) + (\frac{fuel\ cost}{bus})(\frac{\#\ of\ buses}{day})]$$
$$= [((2.5hr)(\frac{\$12}{hr}) + (1.5)(\frac{\$12}{hr}))(\frac{2\ buses}{time\ of\ day}) + (\frac{\$279}{bus})(\frac{4}{day})]$$
$$= [(\$30 + \$18)(2) + \$1116$$

$= \$1212/day$

$$cost\ of\ new\ buses\ = [\frac{cost\ of\ new\ bus}{avg.\ lifetime\ of\ bus} * \#\ of\ buses\ ]$$
$$= \frac{\$375000}{12\ years} * 2\ buses$$
$$= \$62500/year$$

$$yearly\ cost = (\frac{150\ days}{school\ year} * \frac{\$1212}{day}) + \frac{\$62500}{year}$$
$$= \frac{\$181800}{school\ year} + \frac{\$62500}{year}$$
$$= \$244300/year$$

Conclusion: By investing in selective bus stops, it would cost the Santa Cruz Metro ~$244,300 per year.

Selective Bus Stops [w/Leased Loops]

$$total\ cost = Selective\ Bus\ Stop\ +\ Leased\ Loops$$
$$= \$244300 + \$380000$$
$$= \$624,300$$

Conclusion: By investing in selective bus stops and leased loops, it would cost the Santa Cruz Metro and UCSC a combined total of ~$624,300

Selective Bus Stops [w/New Articulated Loops]

$$total\ cost = Selective\ Bus\ Stop\ +\ New\ Articulated\ Loops$$
$$= \$244300 + \$305000$$
$$= \$549300$$

Conclusion: By investing in selective bus stops and new loops, it would cost the Santa Cruz Metro and UCSC a combined total of ~$549,300

Results

Colin McKinnon
Samuel Derlot

The choice has been made to compare only the first and third alternatives because the second one is not working at the same level and it's efficiency is questionable.

Displayed below are the risk profiles and cumulative risk profiles for the first and third solution.

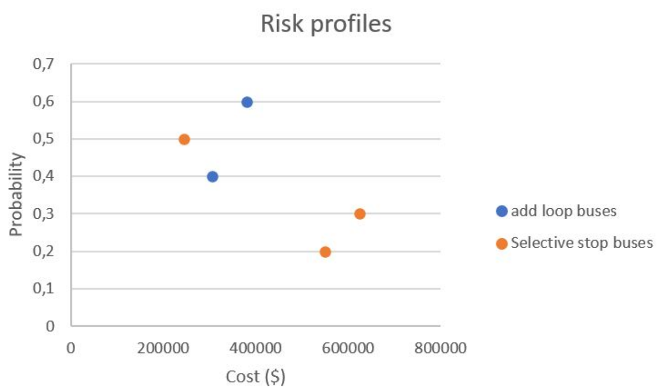

Figure 5: Risk Profiles

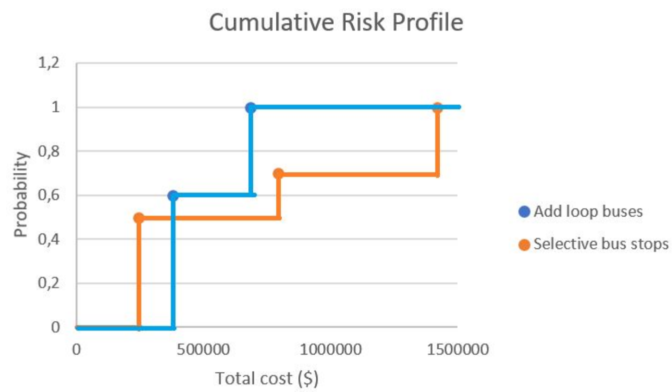

Figure 6: Cumulative Risk Profiles

Below, you can see that we have performed sensitivity analyses on added loop buses, which we found to be the optimal alternative. These analyses were done with respect to the price of gas and the driver's wage. When comparing the two graphs, you can see that the price of gas is a more important variable than a driver's wage. This is because the slope for gas is much bigger than that for driver's wage. Therefore, a small change in price of gas will have a much larger effect, on the total cost, than a small change in the driver's wage.

Figure 7: Sensitivity Analysis (Price of Gas)

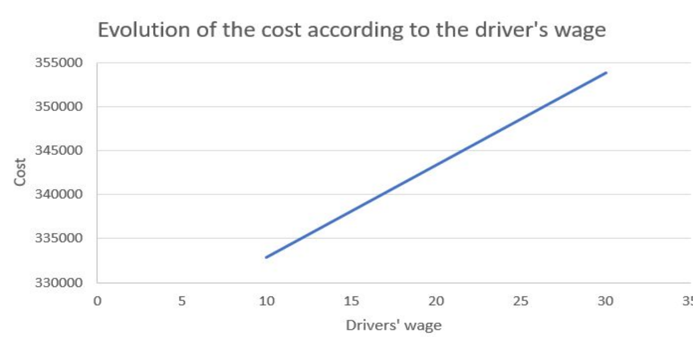

Figure 8: Sensitivity Analysis (Driver's Wage)

Conclusion & Discussion

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Colin McKinnon

When folding back the decision tree, it was clear that the first alternative, adding more Loop buses, was the optimal alternative. This is because its EMV, -$350,000 represents a lower cost than that for selective bus stops, -$549,300. In addition to this, we concluded that the alternative for premium and priority cards was not a sufficient alternative because there was no way to take into account all surrounding factors to quantify the values for cost. Therefore, it would not be an efficient and reliable option in solving our overarching decision, how to reduce traffic congestion during peak times at UCSC.

With this report, we encountered many issues along the way. Our primary roadblock was our ability to get our data and perform analyses on it due to the strikes and the inability of TAPS to be able to work with us during this time. However, using the data we had, we were able to draw reasonable conclusions about the best alternative to mitigating traffic congestion on campus and allow for off-campus residents to reach their homes quicker. In our analysis, however, we also had much bias present that we were unable to mitigate due to the lack of data in their respective areas. Namely, we were not able to determine the likeliness of UCSC or the Santa Cruz Metro in adopting any of the policies due to us being unaware of their decision making process. However, we assumed that all relevant parties would make decisions based on lowest cost / lowest negative EMV.

If we were to perform this research again in the future with ideal conditions, we would attempt alternative routes in data analysis and opt to try and understand the decision making process behind the administration of relevant parties. We would also like to collect data ourselves on when peak hours of transit are, and determine with more certainty what the best possible alternative is.

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