

Reducing Carbon Emissions from Duke Student Transportation

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Executive Summary

Our Bass Connections team wanted to find a way to reduce greenhouse gas emissions from student transportation at Duke University. There are currently no initiatives to address student emissions related to transportation, and they are not included in Duke's Climate Action Plan. Additionally, driving short distances to and from campus is the most inefficient type of driving due to constant accelerating and decelerating which releases more carbon. We developed a survey to gather information on transportation behavior from students living off campus. We sent the survey to a random sample of juniors, seniors and graduate students, and to a sample of peers we could access through various social media groups. The survey results for both samples showed that students who drive to campus often drive alone. Most students also live in a select number of high-density residential complexes. We used the survey to gauge interest in a carpooling app exclusively available to students and found that most respondents were interested to very interested. We decided to design a carpooling app that would decrease the number of inefficient, single-occupancy rides to and from campus and foster a greater student community.

We created a mockup of a mobile application and designed features that would be critical to the app's success. These features respond to carpooling needs and reduce emissions from student-driving, all while ensuring the safety of riders and drivers. We used a focus group to collect qualitative data on features and student demand. The survey responses and meetings with Duke's administration also refined our ideas for incentivizing students to use the app, ideas such as preferred parking spot options or refunds on parking passes.

We determined that this application could have significant social and environmental benefits. Students could use the app to coordinate walks to their cars at night and increase a sense of security. It would reduce the time and stress students without cars expend on finding a way to

campus and would reduce the total number of cars coming to campus and therefore relieve parking congestion. It would also help students develop carpooling habits they will hopefully have for the remainder of their lives. We used data from the survey responses to estimate how much emissions could be saved if students living off-campus used the carpooling app. By increasing the mode share of carpooling to 50%, student-related transportation carbon emissions could be reduced by 25.1%. Our results supported the idea that this app could be a low-cost, high-impact way for the administration to address student-related emissions.

Introduction

Motivation

Duke University is well positioned to make significant environmental and social impacts by demonstrating a deep commitment to sustainability and inspiring other institutions to do the same. Former President Richard Brodhead signed the American College & University Presidents Climate Commitment in June of 2007 (ACUPCC).¹ In 2009, Duke released its first campus Climate Action Plan (CAP), a roadmap for becoming carbon neutral by 2024. Emissions targets were created using the 2007 total greenhouse gas (GHG) footprint as a baseline.² These include GHG reduction milestones every five years starting in 2010, with an ultimate goal of reducing emissions by 88% in 2050.³ The rest of reductions come from carbon offset initiatives.

Since the Climate Action Plan's release, Duke has made significant progress towards this 2024 goal and continues to be a leading institution for climate action. On November 2, 2018, Duke released its 2018 Climate Action Plan Update. Since 2007, the University has reduced GHG emissions by 24%, primarily due to investments in energy efficiency, a transition from coal to natural gas in the campus steam plants, and the reduction in the embedded carbon content of electricity purchased from Duke Energy.⁴ Indeed, despite increasing the campus size by over 3 million gross square feet (GSF) since 2007, Duke has reduced its emissions per GSF by 39%.⁵

While these represent significant improvements, Duke has had particular difficulty in reducing emissions from its transportation sector.⁶ This is mainly a result of the personal nature

¹ *Duke University Climate Action Plan*. 2009, *Duke University Climate Action Plan*.

² *Ibid*

³ *Ibid*

⁴ *2018 Duke University Climate Action Plan Update*. 2018, *2018 Duke University Climate Action Plan Update*.

⁵ *Ibid*

⁶ *Ibid*

of transportation behavior and the lack of regional infrastructure. There are external factors related to transportation that are hard for Duke to control, such as employee commuting and air travel. At the same time, as of fiscal year 2018, transportation-related activities accounted for nearly 79,000 metric tons or 31% of Duke's overall carbon emissions.⁷ Employee commuting represented 16% of Duke's total emissions, with 80% of university employees driving alone to work.⁸ While Duke has reduced emissions from almost all other sectors, Duke's emissions from transportation-related activities have risen 9% (compared to the 2007 baseline).⁹

With respect to transportation, Duke's Climate Action Plan focuses exclusively on faculty and staff and does not address student-driving behavior. Duke does not account for student-related transportation emissions in its calculations. Looking at undergraduates alone, 19% of students live off campus or commute to campus, or roughly 1,270 undergraduate students.¹⁰ With about 9,602 students enrolled in Duke's graduate programs, this would suggest that over 10,000 additional individuals commute to Duke on a weekly basis—a significant contribution to emissions. The Sustainability Office is currently exploring how it can use Scoop, a carpooling platform that targets professionals, to reduce the number of faculty and staff driving alone to work. However, there are no initiatives to address student-related transportation emissions.

Our Plan

Our Bass Connections team decided to focus on addressing transportation-behavior, specifically for students living off-campus. After meeting with the Duke Sustainability Office,

⁷ *Ibid*

⁸ *Ibid*

⁹ *Ibid*

¹⁰ "Duke University." *College Data*, www.collegedata.com/en/college-profile/1026?tab=profile-overview-tab.

we created a survey to learn more about student-driving behavior and gauge interest in a carpooling application made specifically for students. We sent out our survey to different samples of juniors, seniors and graduate students. There was a significant positive response to the idea of a carpooling app from both undergraduate and graduate respondents. The survey demonstrated that this app could be a low cost, high impact way to decrease student emissions, all while addressing student needs for transportation to and from campus and aligning with Duke's broader environmental goals. The responses also informed our design and gave us a better understanding of the scope of the problem, our target group and the size of potential benefits, both environmental and social. We learned from our data that increasing the mode share of carpooling to and from campus could significantly reduce emissions from one of the most inefficient modes of driving.

As the administration continues to address other on-campus energy inefficiencies and transportation-related behavior for employees, we believe addressing student behavior will be an important next step in Duke's Climate Action Plan.

Methodology

Interview with Duke Sustainability Office

The first step in designing our app was to meet with Duke administration. Our group wanted to create a carpooling app, but needed to ensure that there was demand for one. We met with the Duke Sustainability Director and Assistant Director, Tavey Capps and Jason Elliot and learned that Duke did not track the emissions from student transportation. Although the Sustainability Office is developing a carpool app for faculty and staff, they did not have plans

for an app geared towards students. Through this meeting, we learned that our app could provide a much-needed way for Duke students to reduce their transportation-related carbon emissions.

Survey of student transportation behavior

A short Qualtrics survey was created in order to collect data on the transportation habits of Duke graduate and undergraduate students. The survey asked participants their class year, where they live, how they normally travel to/from campus, how many times they went to campus in a week, their interest in carpooling, and which incentives for carpooling would provide the best motivation to carpool (see survey questions in **Appendix A**). These questions were created after viewing other similar surveys done on campuses in the past.¹¹ In order to send our survey to the email addresses of a random sample of Duke students, we completed a training module from Duke's Institutional Review Board (IRB) and submitted the survey to the IRB for review. Our random sample included 200 seniors, 200 juniors and 400 graduate students. To gather as much data as possible, a version of the survey was sent out to students through various forms of social media, such as the "All Duke" group on Facebook. With information from the survey, we met with Tom Devlin from the Duke Transportation Office. He reviewed our data and our proposed incentives, and clarified which incentives would best align with what the Duke administration would be willing to provide.

Development of the Carpooling App

Throughout the process of meeting with the administration, app design began. Members of the group are familiar with several ridesharing apps such as Uber, Lyft, and DukeVans. Using knowledge of these apps, possible features were brainstormed in order to make the carpooling

¹¹ Heckathorn, Drew. "Results of the 2016-17 Campus Travel Survey." Institute of Transportation Studies and Parking Services, University of California, Davis. July 2017.

app as safe and user-friendly as possible. After each meeting with the administration, their advice was incorporated into the design of our app. Our class acted as a focus group (11 undergraduates) to get feedback from students (see focus group questions in **Appendix B**). We made several changes to the app and added new features in order to address the concerns raised by those in our focus group.

Technical Design

The goal of our carpooling application is to decrease student emissions in a high-impact, low-cost way. From a design perspective, our interface should be easy for both riders and drivers to use. The app needed to ensure that a student would get to class and home on time, so we looked at ways to match riders and driver based on timing and to make both parties accountable for timeliness. We also wanted to include several safety features, to ensure both our riders and drivers felt comfortable and secure during their carpools.

Riding with our App

All riders/drivers need to sign into the app with their NetID and passwords. This will ensure that all users of the app are Duke students. Ensuring that the user was affiliated with the university was also shown in a survey at Michigan State University to increase use of a carpooling service.¹² The app will use individuals' Duke card pictures for their profiles (Figure 1). This will help riders/drivers identify one another.

¹² Kaplowitz, Stan. A, and Arthur Slabosky. "Trying to Increase Carpooling at a Major U.S. University: A Survey and an Intervention." *Sustainability: The Journal* 11.2 (2018). 74-80.

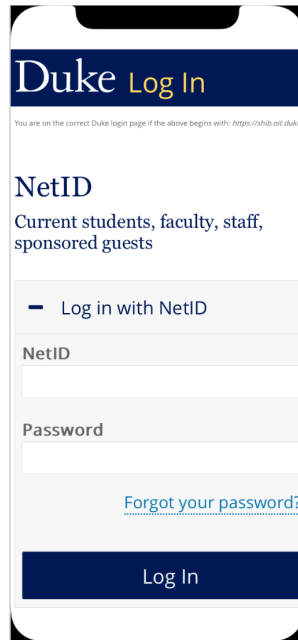


Figure 1: Log-in with NetID.

At the most basic level, the app needs to be able to match a rider with a driver based on location and time. When the user opens the app and signs in, they are greeted with an interface that allows them to select whether they are a rider or a driver, the time they need to be on campus or at home by, and where they are coming from or going to. The options for locations will be a number of predesignated meeting spots: for off-campus this will include different apartment complexes/popular neighborhood locations (The Heights at Lasalle, Berkshire Ninth Street); for on-campus this will include specific spots outside major buildings (Perkins Library, West Union) and in parking lots (Bryan Center Surface Lot, Blue Zone 1, etc.).

Once the user enters in this information, the application will match her with a list of riders/drivers who are looking to complete the same trip or as close to it as possible. The options will be listed in order of relevance, with the highest-rated trips that are closest to the user's desired timing at the top. She can select to be in a carpool up to 24 hours in advance. As a rider, the user can select a driver from the list to enter a carpool. If she knows the name of a specific

driver whose carpool she wants to join, she can search for this. The driver will receive a notification once the rider has entered her carpool. As a rider, the user can see when the driver has arrived at her designated location. There will be a built-in chat on the application for all members of a carpool to communicate.

The user will also have the opportunity to filter carpooling options. If she is a driver, she can select how many spots she wants to offer in the car (although there needs to be at least two passengers in the vehicle not including the driver to qualify for carpooling benefits). The user can also add someone into the carpool (e.g. a friend who she knows will be carpooling with that day). As either a driver or a rider, users can filter *who* they drive/ride with. These selections include smoker/non-smoker, male/female, anyone/mutual friends/friends only. The anyone/mutual friends/friends only selection is part of our “friends” feature, which allows a user to friend other drivers/riders on the app who will then appear as friends when creating a carpool (Figure 2).

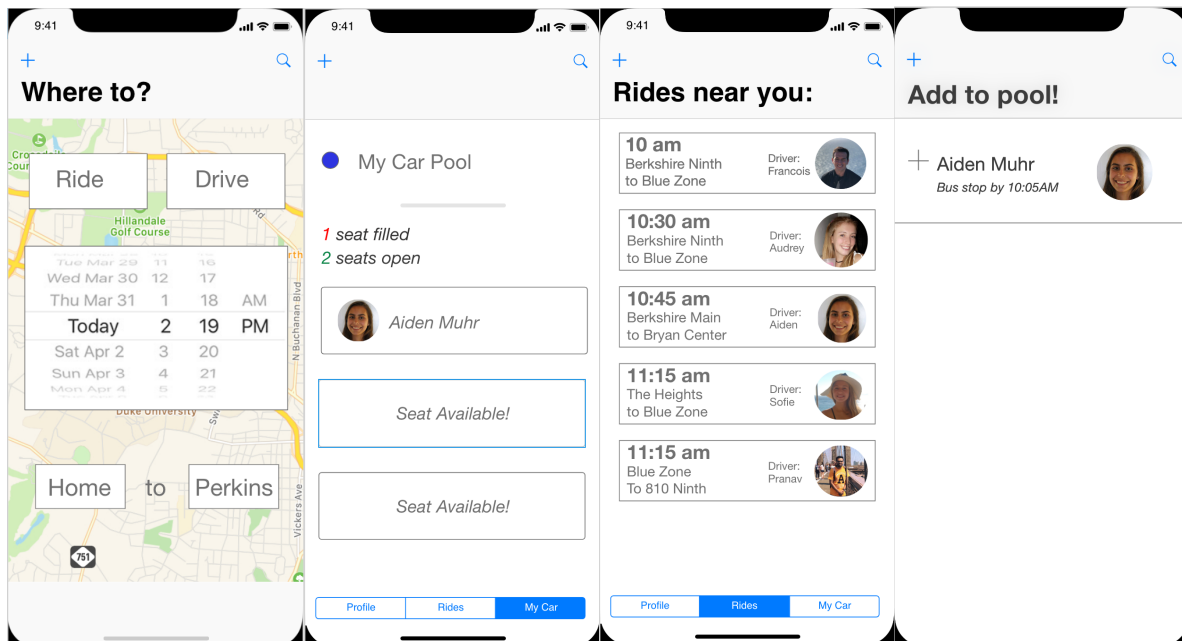


Figure 2: Mockups of the rider and driver interface for the carpooling app. Far left: scheduling a ride or drive. Second from the left: driver viewing their carpool. Second from the right: viewing your carpooling options/results. Right: adding friends to carpool.

Additional Features

Friends feature: As mentioned before, the app will have a friending feature similar to Facebook, where users can add friends on the app. They can use this feature to filter driver/riders. For example, when creating a carpool the user can select “friends only.” If she is a driver, only people she is connected with as friends on the app will be able to see that she is driving and add themselves to the carpool. If she is a rider, she will only see drivers who are “friends.” This filter can also be used with mutual friends, so only mutual friends on the app show up in the user’s searches (Figure 3). According to one study at Mahasarakham University, the issue of who students would share their ride with is one of the most important issues of the service. It found that most students would want to share a ride with a friend, emphasizing the importance of the friends feature.¹³

¹³ Singhirunnusorn, Wichitra, Preeda Luesopa, Jiraluk Pansee, Nopadon Sahachaisaeree. “Students Behavior towards Energy Conservation and Modes of Transportation: A Case Study in Mahasarakham University.” *Procedia - Social and Behavioral Sciences* 35 (2012). 764-771.

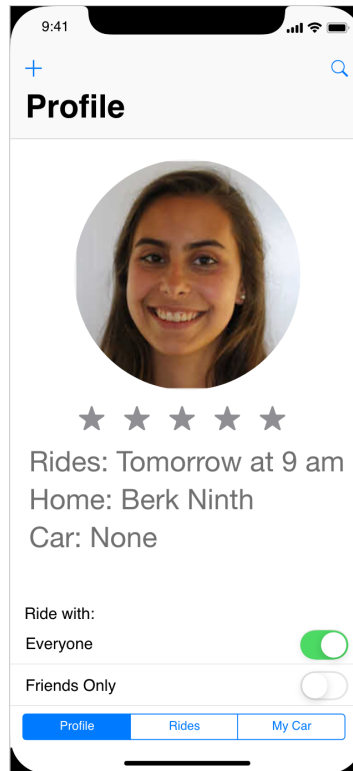


Figure 3: Choose to ride with friends, mutual friends, or everyone.

Rating feature: For the carpooling app to be effective, students still need to get to class or home on time. In order to increase accountability for timeliness, the app will have a rating feature. The rating will be out of five stars. If a driver/rider is consistently timely, enjoyable to ride with, respectful, etc., he/she will get a high rating. If a driver/rider is consistently late, unpleasant, disrespectful, etc., the user can give them a low rating or even report the driver/rider. The lower the rating as a driver, the lower one will show up in someone's search results. If the user is a high-rated driver, she will get matched with high-rated riders. This rating system will be similar to Uber's matching process. The rider will also be prompted with questions when they are rating, such as: "Was your driver on time?"

No-ride list: There may be people on campus who make someone uncomfortable or who they would not want to be in a car with. With this in mind, we've also created a "no-ride list" feature. From your profile you can add specific individuals to your "no-ride" list. These individuals will

never be able to see the times you post as a driver and they will not show up as a potential driver. They will never be able to enter your carpool through the app, and if the person is a rider in another carpool that carpool will not show up in your results. This feature was included to help people feel safer using the app.

Built-in chat: As mentioned before, there will be a group message feature built into the app that includes all members of the carpool. This group-chat can be used for a driver to indicate that they have arrived, to ask about each members' whereabouts/ETA, to find the car's specific location within a parking lot or even to coordinate walking to the car together. This can be particularly beneficial in cases where the driver/rider does not want to walk alone to the car, such as at night. The group-chat is included as part of the app so that members of the carpool do not have to disclose their personal phone numbers to communicate. This will help enhance the social and safety benefits of the application.

Carpooling Incentives

The biggest value-add for our drivers is the potential benefit they receive from carpooling. We considered what reasonable incentives could be offered to a student carpooling to and from campus and came up with two options: better parking spots and refunds on parking passes. These options seemed to be consistent with other comparable carpool incentive programs, which recommended preferred parking, reduced cost or free parking, and prizes offered through friendly competition or reward programs.¹⁴ These programs also emphasized increasing the ease with which potential commuters could match.¹⁵

¹⁴*Carpool Incentive Programs Implementing Commuter Benefits as One of the Nation's Best Workplaces for Commuters*. United States Environmental Protection Agency Office of Air and Radiation, Nov. 2005.

¹⁵ Mckimmy, Matt. "How to Encourage Employees to Carpool." RideAmigos, Matt Mckimmy <https://rideamigos.com/Wp-Content/Uploads/2016/12/Ra-Asphalt-600x175.Png>, 15 Apr. 2019, rideamigos.com/blog/how-to-encourage-employees-to-carpool/.

Our options were evaluated based on demand and feasibility. This required consumer-research and coordination with Duke's administration. Our surveys suggested that the student body seemed to have relatively equal preference for the two incentives. Other considerations included how it could be verified that a driver was actually filling spots in their carpool, in other words, who was eligible to receive benefits, and how to avoid loopholes.

Once a carpool has begun (reminder: a driver needs two other passengers in their car for Duke to consider it a carpool), the app would produce a unique barcode for the driver (Figure 4). The driver could scan this barcode instead of his/her typical parking pass at the entrance to different parking lots (i.e. Blue Zone). The app would verify that there was actually X number of riders in the car, and the barcode would allow Duke to register the carpool, including how many individuals were in the carpool.



Figure 4: Barcode Feature.

Better parking spots: One potential benefit for carpoolers would be preferred parking spots on campus. The original plan included designated spots in the Bryan Center parking lot or in the Sanford parking lot. After conversations with Duke's administration, it seemed the

administration might be more inclined to offer preferred parking in lots that already require parking passes, such as Blue Zone. For example, there could be three or so rows of parking spots in Zone 1 & 2 reserved for car-poolers. Transportation Enforcement could make sure the cars parked in these spots are actually car-poolers by checking their license plate, which would be linked to the barcode the driver scanned at the entrance of the parking lot.

Refunds on parking passes: Refunds would be a feature built into the application. Duke could offer the driver a partial refund on his/her parking pass either at the end of the semester or on a monthly or weekly basis based on the number of carpool trips made and the number of people in each carpool trip. These trips would be recorded by the barcode scanned at the entrance to parking lots. Further conversations with Duke's administration are needed to determine what would be a realistic or fair amount for this refund. However, Tom Devlin, the program manager for Transportation Demand Management at Duke Parking & Transportation indicated that the administration would likely be more agreeable to this incentive over preferred parking.

Consumer Research Analysis

Survey Analysis

In our efforts to determine Duke students' transportation behavior, we sent out a survey to two different samples of students. For the first sample (Sample 1), we collected responses through social media. For our second sample (Sample 2), we sent our survey to the email addresses of a randomly selected group of 200 seniors, 400 juniors and 400 graduate students, provided by the Duke Office of the Provost, Finance & Administration. Sample 1 generated a total of 148 responses, out of which there were 89 graduate students, 21 juniors, and 38 seniors. Sample 2 included the responses of 58 graduate students, 38 juniors, and 24 seniors for a total of 120 responses. Sample breakdown by grade is shown in Figure 5.

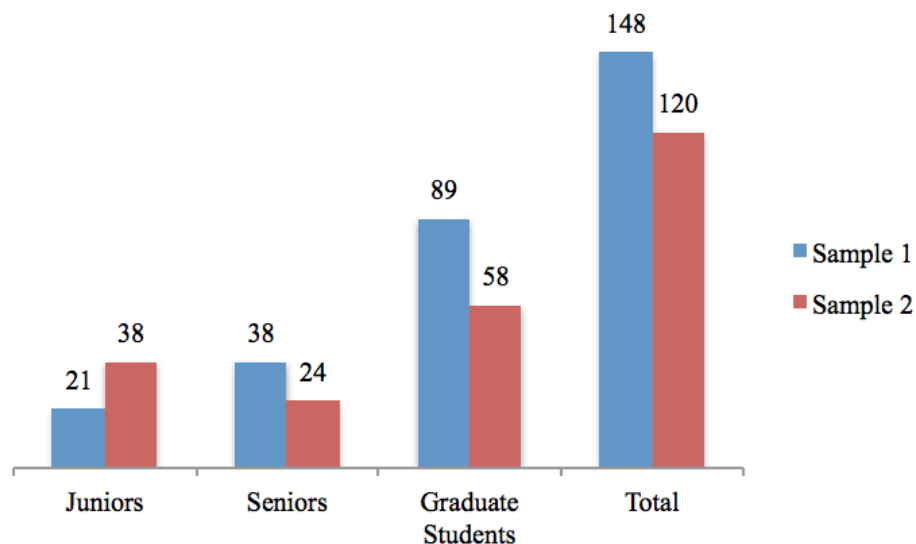


Figure 5: Response Breakdown by Student Class for each sample.

The survey focused on juniors, seniors and graduate students because these students are less likely to live on-campus and our carpool app specifically targets students living off-campus. Results from the survey supported our initial hypothesis that a large number of juniors, seniors, and graduate students reside off-campus, and should be our target market. In Sample 1, 136 out

of the 148 respondents reported living off-campus and in Sample 2, 79 out of the 123 respondents. The subtle difference in the proportion of students living off-campus between the two samples may be partially explained by the low number of seniors in Sample 2.

In our survey, students were asked where they live off-campus and provided a list of residential complexes nearby (results for this question are shown in Figure 6).

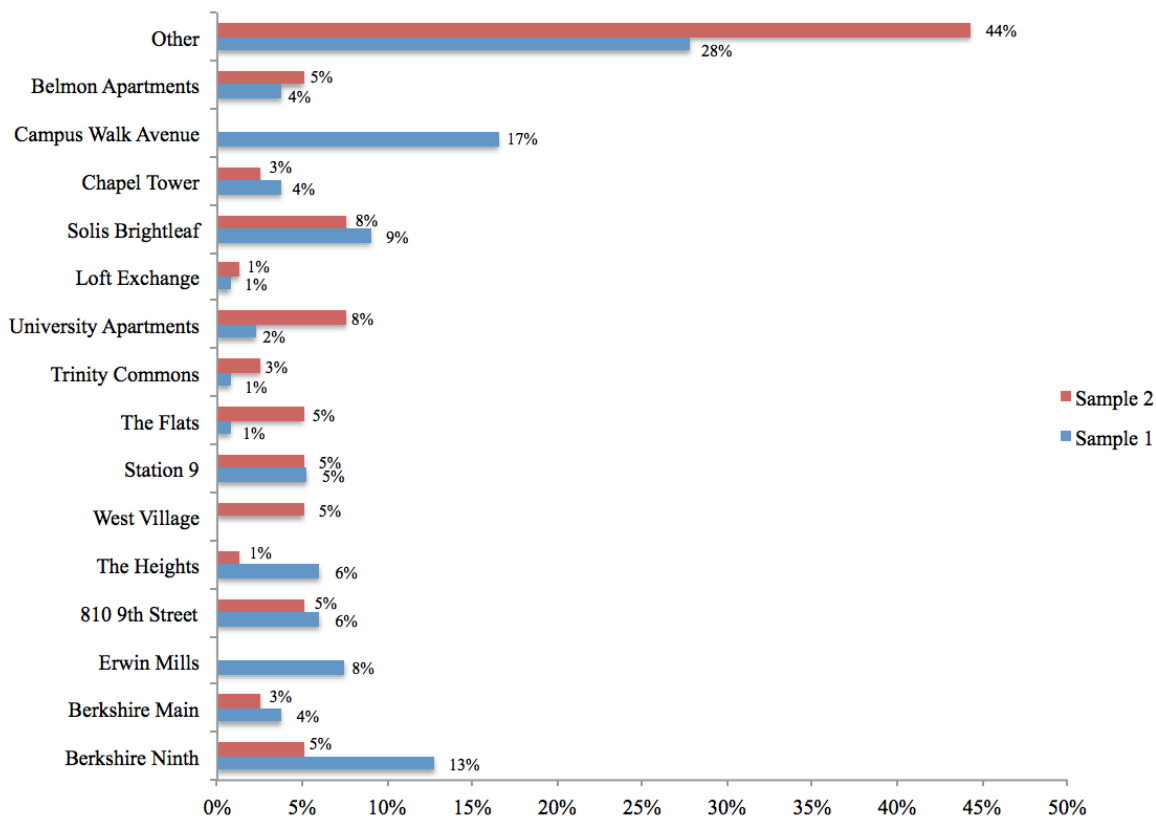
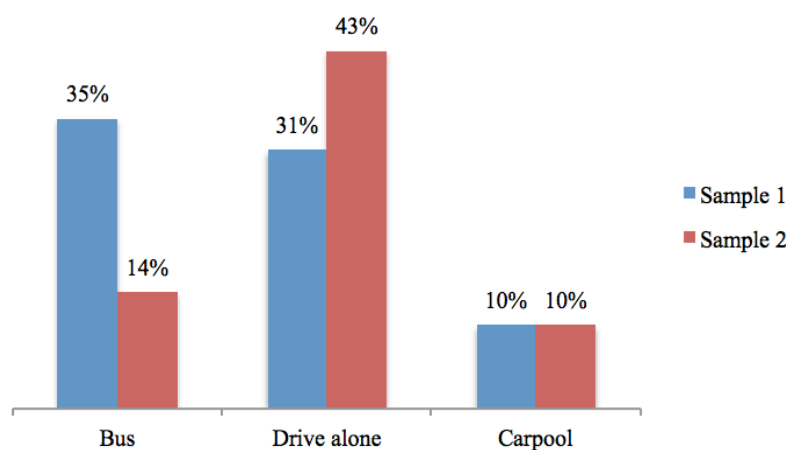


Figure 6: Graph showing breakdown of where students live.

Out of all respondents in Sample 1, 72.18% stated that they live in one of the listed options. Of these, only 26% of graduate students and 29% of juniors and seniors do not live in the proposed residential buildings. All undergraduates who selected “other” for their living arrangement were seniors and mentioned living in houses. This was predictable given that many of the respondents from the survey sent through social media are involved in Greek life or Selective Living Groups, organizations where seniors will often live together in houses.

In Sample 2, 56% of respondents said they live in one of the listed apartment buildings. This percentage is low when compared to that of Sample 1 because 58% of graduate students reported not living in the listed buildings. Only 13% of juniors and seniors did not live in these residences. The main takeaway from our Sample 2 results is that juniors and seniors tend to live in more concentrated areas than graduate students, who live more dispersed throughout Durham. Overall, the high density of the students targeted in large apartment complexes (weighted average of 70% of respondents living in listed buildings between both samples) would allow for a more efficient selection of pickup and drop-off locations for the carpooling app. According to research done at the University of New Hampshire and the University of Rhode Island, longer commute distances discourage alternate transportation use, including carpooling.¹⁶ The concentration of Duke students close to campus with short commutes is thus promising for switching from single-occupancy drives to other transit modes, such as carpooling.

Understanding students' transportation habits to and from campus was one of the main purposes of our survey. One of our questions asked participants how they get to campus (Figure 7).



¹⁶ Fu, Tat, Norbert Mundorf, Colleen A. Redding, Leslie Brick, Andrea Paiva, and Jame Proschka. "Exploring Sustainable Transportation Attitudes and Stages of Change Using Survey and Geospatial Data in New England Campus Commuters." *Journal of the Transportation Research Forum* 55.2 (2016). 71-90.

Figure 7: Graph showing student transportation choices to get to campus.

The majority of students living off-campus in Sample 1 take the bus to get to campus, 31.06% drive alone, and only 10% carpool. The results of this sample show that graduate students are more likely to take the bus than undergraduate students (44% vs. 23%). However, the percentage of juniors and seniors driving alone to campus is much higher than that of graduate students (56% vs. 16%). The percentage of respondents who carpool is very similar for graduate students and undergraduate students, at around 10%, showing that there is a large potential to change students' transportation behavior.

Sample 2 shows different results in terms of the percentage of students that take the bus but similar results for the drive alone rate and proportion of students carpooling. Only 13.92% of students living off-campus take the bus, while 43.04% drive alone and 10% carpool. Furthermore, it is important to note that drive alone rates were higher for juniors and seniors than graduate students in both samples. This consistency between both samples may be explained by the fact that many undergraduate students are financially dependent on their parents, who are better positioned to own a car, while graduate students are young professionals who might not be able to afford a car yet. Thus, our goal of reducing energy and emissions from drive alone trips would be maximized if the app targeted juniors and seniors.

Survey results show that students go to campus 5 times a week when taking the weighted average of both samples. Juniors go to campus the most often, followed by seniors and graduate students (Figure 8).

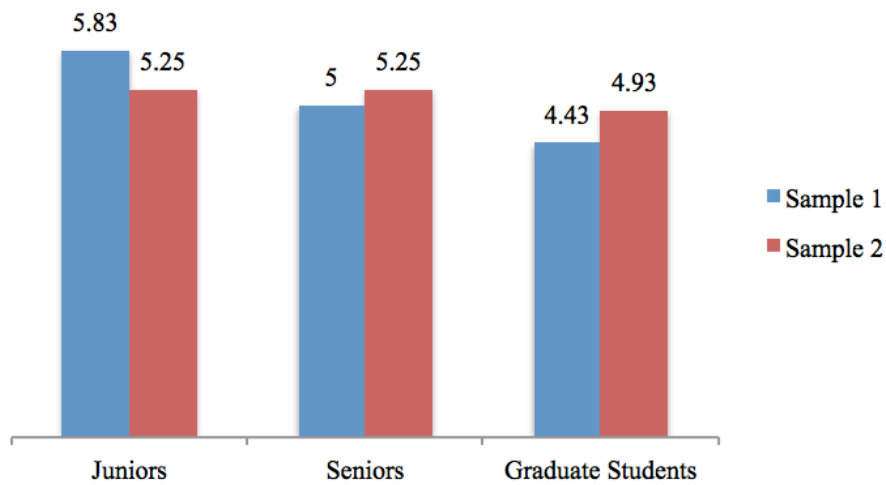


Figure 8: Graph showing the number of times a week students get to campus by car.

Graduate students often have longer classes packed into fewer weekdays and do not need to go to campus on days when they do not have classes. Juniors and seniors have similar schedules, but the latter may have fewer classes if they part-time (take 2.5 credits or less).

Our survey also gauged the level of interest that respondents would have in a carpooling app. In both samples, 80% of respondents living off-campus said they would be interested in using a carpooling app. Graduate students are slightly more interested in the carpooling app than juniors and seniors, but the difference is minimal (Figure 9).

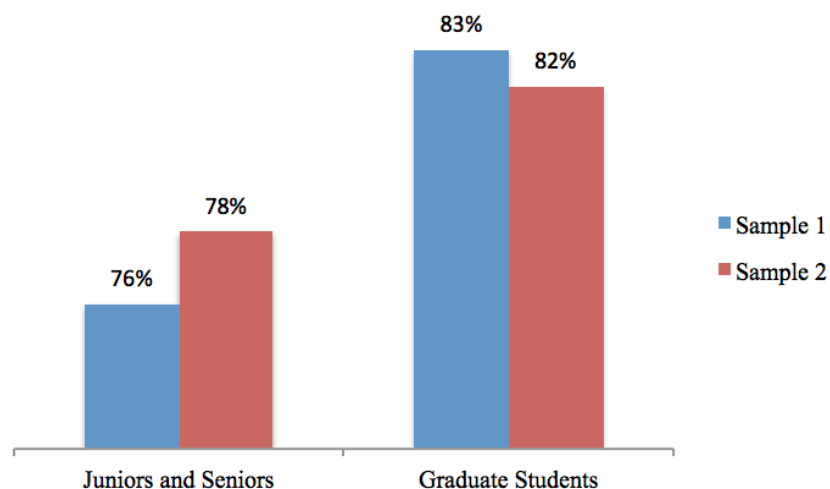


Figure 9: Graph showing the percentage of students interested in using the carpooling app.

The widespread support of the carpool app from students surveyed is a positive step in the idea's implementation. Not only does it reflect that students have a desire to shift to greener transportation habits, but it also prompts Duke to implement a carpool app that will allow them to reduce the university's transportation-related emissions.

The survey also explored what incentives Duke could offer to encourage students to stop driving alone and start carpooling. Survey results showed that both a reimbursement on the students' parking pass and the ability to park in a better parking spot are reasonable incentives to encourage students to carpool (Figure 10).

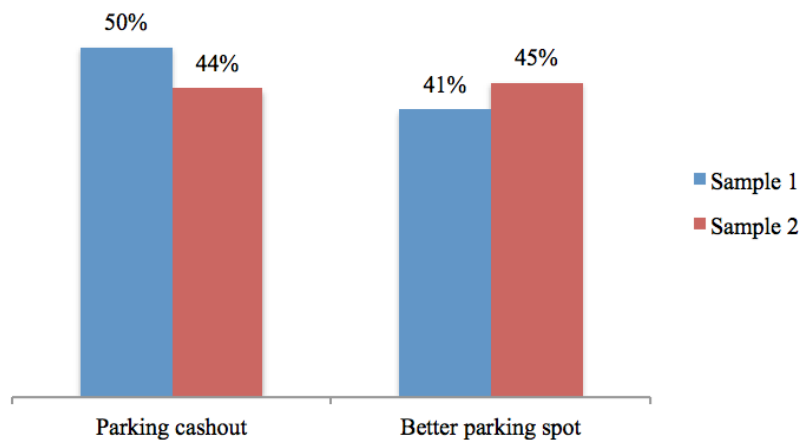


Figure 10: Graph showing students' top choice incentive to carpool.

In Sample 1, 50% of students living off-campus prefer to get money back on their parking pass, while 41% would rather park closer to campus. Sample 2 shows similar results, with 45% of respondents wanting a better parking spot and 44% preferring a reimbursement. Graduate students would rather park in the Science Drive or Visitor next to JB Duke while juniors and seniors consider the BC Lot and the first two lots of the Blue Zone good parking locations. This is likely due to the locations of undergraduate and graduate classes. Tom Devlin, Manager for

Transportation Demand at Duke, suggested that a cash-out system on parking passes would be more viable option than giving students preferred parking spots, but the latter could be obtained with restrictions on certain parking lots. According to the Michigan State Survey, non-economic incentives, such as a better parking spot, would increase carpooling interest more than modest financial ones, but large financial incentives would result in the most interest.¹⁷ Because the survey did not state how large of a financial incentive carpoolers would receive, this data is relatively consistent with our survey responses.

Focus Group Insights

We conducted an 11-person forum to gather more qualitative information on how to develop the carpool app and what features we should include. From our discussion, we received the following insights:

1. *Safety is a main priority for students*

- Students want to know that they are safe when they get into a car with other people. The app should only include Duke students and require drivers and riders to login with their Duke NetID. All students using the app should have a profile photo with their account.
- Most undergraduate students feel comfortable carpooling with graduate students, so an inclusive platform with both undergraduate and graduate students is possible.
- Students want a ranking system to help them decide who to carpool with. They suggested anonymous rankings. In addition, ratings should be broken down into sub-sections such as “safe driving,” “reliability,” and “friendliness.” Both drivers and riders should have a rating.

¹⁷ Kaplowitz, Stan. A, and Arthur Slabosky. “Trying to Increase Carpooling at a Major U.S. University: A Survey and an Intervention.” *Sustainability: The Journal* 11.2 (2018). 74-80.

- Drivers want to receive a request from riders to join their car, which they can accept or reject.
- Students want to be able to link their profile on the app with social media platforms like Facebook, to see which of their friends use the application (or who they have mutual friends with). That way, they are able to identify potential drivers/riders.
- In the case that students feel uncomfortable sharing a ride with another Duke student, they want to have the option to block them.

2. *A simple and integral platform would make the carpool app more popular*

- The interface should be friendly to use and its own application, rather than a portal within DukeMobile.
- Students want to be able to filter drivers based on features such as smoker vs. non-smoker and female vs. male. This will allow them to match with a driver that they feel the most comfortable with.
- Students who own a car would be willing to give up all spots in their car as long as they still receive benefits from doing so.
- Photo requirements will allow drivers and riders to identify each other faster
- Communication between members of the carpool is crucial. Students prefer a built-in chat in the app, rather than texting with their personal numbers.

3. *The application needs to effectively get students to and from class/home and leave enough time to find alternatives if there is no available carpool.*

- Potential riders want to avoid stress related to not getting to class on time or not finding a ride to go back home. Therefore, riders want to be able to schedule rides at least one hour in advance to be able to make other plans if there are no drivers available.

Environmental Benefit Analysis

Using the results from our surveys, we conducted an environmental benefit analysis. This analysis quantifies the benefits our application might have, as more students shift from driving alone to carpooling. This section provides our methodology for calculating the environment benefit analysis based on reduction in CO₂ emissions. The survey results were used to calculate the associated emissions and reductions with the anticipated shift toward carpooling.

Methodology

The survey results gave us data about number of commuting passengers, how many of them drive alone and how many carpool, total number of trips in a week and average distance driven. From these data points, we calculated the number of vehicles being driven, and hence total miles driven in a week. Average fuel economy numbers for US cars¹⁸ and CO₂ emitted per gallon of gasoline burned¹⁹ were used to calculate the weekly CO₂ emissions from student commuting.

Data

Table 1: Data regarding number of students driving alone and carpooling to campus

Students driving alone to campus	5470
Students carpooling to campus	1077
Total student commuters	6547

Table 2: Data regarding car trips to/from campus

¹⁸ Transportation Energy Data Book, Oak Ridge National Laboratory, Table 4.1

¹⁹ Transportation Energy Data Book, Oak Ridge National Laboratory, Table 11.12

Average number of one-way trips per week	5.5
Total number of trips per week	11
Average distance per trip (miles)	2.5

Table 3: Data regarding fuel use²⁰

Fuel Economy* (miles/gallon)	20
CO ₂ emitted per gallon of gasoline (lb CO ₂ /gallon)	19.6

*Average fuel economy for all US cars is 26.2, but we assume it to be less, because in our case, it's predominantly city driving, so it's safe to assume a number less than the national average, which includes both city and highway driving.

Table 4: Data regarding occupancy**

Drive Alone	1
Carpool	3

**Occupancy - Occupancy simply means, on an average, how many people are there in one vehicle. For drive alone, occupancy will be 1, because it's just one person driving the vehicle. For carpool, occupancy can range from 3 to 5, depending upon the total capacity of the car. According to Duke Parking Office, a car is qualified for a carpool if there are at least 3 people in the car, hence we assume the number to be 3, taking a conservative approach.

Calculations

1. Mode Share

Mode Share tells us what percentage of people travel through each mode, i.e. drive alone, or carpool. According to the survey results, the current mode share for Drive Alone is **84%** and for Carpool is **16%**

²⁰ Transportation Energy Data Book, Oak Ridge National Laboratory

2. Number of vehicles commuting to and from Duke

Our next step is to figure out how many vehicles actually commute to and from Duke, For this, we used the following formula -

Number of vehicles - Mode Share*Total Commuting Population/Occupancy

If occupancy = 1, we will get vehicles equal to total population driving alone, but if occupancy = 3, then the number of vehicles would decrease as compared to the people carpooling, as one car can fit 3 people.

Therefore, number of drive alone vehicles = $0.84*6547/1 = 5470$

Number of carpool vehicles = $0.16*6547/3 = 359$

Total Vehicles commuting to and from Duke = **5829**

3. Weekly Vehicle Miles Driven

Once we get the total number of vehicles driven, we need to calculate how many miles are being driven every week. For that, we used data about weekly trips and average distance per trip. This step is important because once we get the total miles driven, we can calculate how many gallons of gasoline is being used every week, and hence estimate weekly CO₂ emissions.

Miles Driven per vehicle per week = Total trips per week*Average Distance per trip
 $= 11*2.5 = 27.5 \text{ miles}$

Now, we know the total number vehicles for each mode, hence we can calculate total vehicle miles driven. Total Vehicle Miles simply tells us how many miles are being driven by all the vehicles.

Total Weekly Vehicle Miles for Drive Alone Vehicles = $27.5*\text{Number of drive alone vehicles}$
 $= 150425 \text{ vehicle-miles}$

Total Weekly Vehicle Miles for Carpool Vehicles = $27.5*\text{Number of carpool vehicles}$

$$= 9872.5 \text{ vehicle-miles}$$

4. Weekly CO₂ emissions

Now the final step is to calculate the CO₂ emissions from both modes. We now have the total miles being driven weekly, we will convert those miles to gallons of gasoline being consumed by dividing with the fuel economy, and multiply this term with the CO₂ emitted from 1 gallon of gasoline to get our final number. The resulting CO₂ emissions will be in pounds, and we divide it by 2000 to convert to tons.

The formula is as follows -

$$\text{CO}_2 \text{ (tons)} = (\text{Vehicle Miles/Fuel Economy}) * (\text{CO}_2 \text{ emitted per gallon of gasoline}) / 2000$$

$$\text{CO}_2 \text{ (tons) from Drive Alone Mode} = (150425/20) * (19.6) / 2000 = \mathbf{73.7 \text{ tons}}$$

$$\text{CO}_2 \text{ (tons) from Carpool Mode} = (9872.5/20) * (19.6) / 2000 = \mathbf{4.8 \text{ tons}}$$

5. Reductions in CO₂ with anticipated shift toward carpooling

The final step is to calculate the emissions reductions as more students shift toward carpooling from drive alone with the use of our app. The current mode share is 84% drive alone and 16% carpool. Assuming that our app can lead to the new mode share of 50% drive alone and 50% carpool, we can see a **25.1%** reduction in CO₂ emissions. The following graph shows these results.

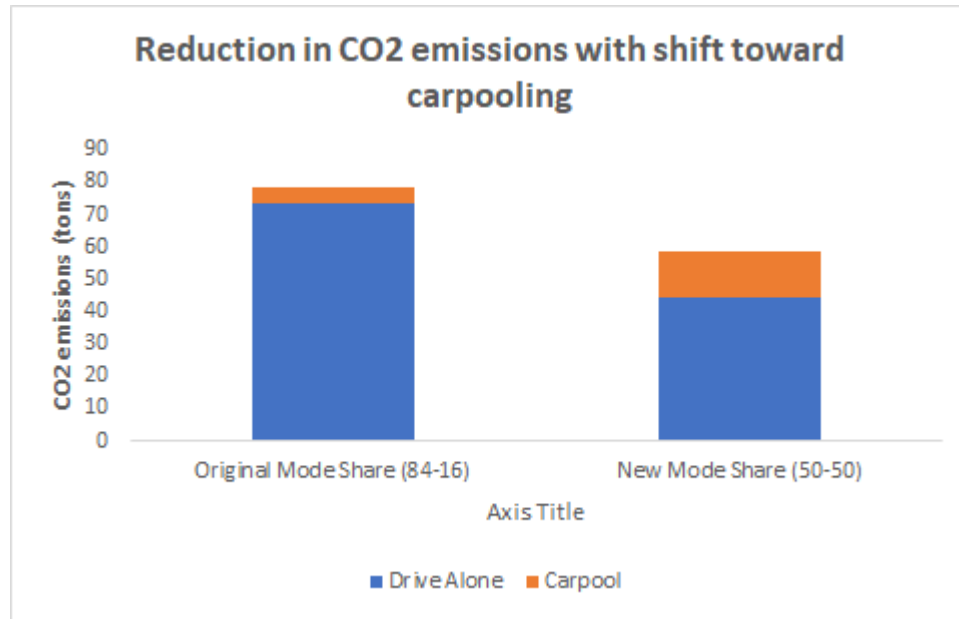


Figure 11: Reductions in CO₂ emissions with shift toward carpooling.

Social Benefit Analysis

There are several social benefits derived from our carpooling app. First, students will feel safer when walking to and from their cars on campus if they have someone with them. Especially at night, many parts of campus are not well lit. The student parking lot on West Campus, Blue Zone, is far from the library and the walk has several stretches that are dark. In September of 2018, there was a mugging on Towerview Road which is the road between the main part of West Campus and Blue Zone.²¹ The Chronicle reported that students often feel uncomfortable even walking the short distance from Perkins Library to the Allen lot across the quad.²² By using the app, students can be certain they will have someone to walk to their car with, and hopefully will make them feel safer.

The second benefit is the access to a vehicle that many will now have through carpooling. The bus system can be tricky to navigate when living off-campus. Often times when a student takes the bus, he or she ends up arriving very early or late for class. The bus does not always arrive on time or it arrives early which discourages students from using the public transportation system. Walking to campus may take a long time or feel unsafe after daylight hours. For many Duke students who have already-busy lives, taking public transportation or walking can feel like a burden. Being able to use a car to drive to campus lifts this burden, but not everyone can afford a personal car. With the carpool app, these students will have easy access to rides to and from campus that they don't have to plan their entire day around.

Thirdly, Duke students are still at the age when habits they build are formative. One Harvard study suggests that long-lasting change most often occurs when it is self-motivated and

²¹ Bradham, Bre and Leonard, Ben. "Armed robbery attempt reported in Wannamaker fire lane." *Duke Chronicle*, Sept. 17, 2018. <https://www.dukechronicle.com/article/2018/09/armed-robbery-reported-near-wannamaker-dorm>

²² Fang, Shannon. "How safe is Duke? Reality versus perception of campus crime." *Duke Chronicle*, April 4, 2018. <https://www.dukechronicle.com/article/2018/04/how-safe-is-duke-reality-versus-perception-of-campus-crime>

from a positive space.²³ The carpooling app will help students build a habit of carpooling in a positive way. They will be rewarded for carpooling with either refunds on their parking passes or better parking spaces and hopefully will carry the habit of carpooling with them into their adult life.

A fourth benefit is that less cars will be driven to campus. Currently, student lots such as Blue Zone are always filled with cars. Many students arrive to the parking lot only to spend 15-20 minutes looking for a space to park. If less cars total are driven to campus then lots will be less crowded. Lastly, we believe that carpooling may help foster community on campus with students getting to know people who they would not have otherwise met.

²³ Harvard Women's Health Watch. "Why it's hard to change unhealthy behavior - and why you should keep trying." January, 2007. https://www.health.harvard.edu/newsletter_article/why-its-hard-to-change-unhealthy-behavior-and-why-you-should-keep-trying

Business Plan

Target market

The target market for our app is Duke students both graduate and undergraduate. The results of our survey showed that many graduate students take the bus or bike to school, however a significant number still drive alone. While we do not want to take away students from the bus - a cleaner form of transportation -- there are enough graduate students who drive alone to warrant their inclusion in our target market. Our survey results indicated that about 80% of participants are somewhat to very interested in carpooling to campus. Therefore, there is enthusiasm from the students (our target market) about the possibility of carpooling (our product).

Looking forward

The app would be free to all students in order to encourage carpooling. The costs to create a prototype of the app have been minimal. The prototype was designed on Adobe Creative Cloud XD CC, a software that is available to all Duke students for free. The survey was also free to produce and distribute through Qualtrics. We propose that the actual development of the app would be undertaken by the Duke administration. It is hard to say the exact cost of developing an app because there are many different factors that can make an app more or less expensive to develop. Endive Software estimates that the cost of developing a ridesharing app is about \$15,000 with U.S. based software developers charging \$80-250/hour.²⁴ Duke would almost certainly be losing money in creating the app. However, financial gains cannot be the only

²⁴ Goyal, Ajay. "How much does it cost to build a carpooling app like BlaBlaCar?" *Endive Software*. Accessed April 26, 2019. <https://www.endivesoftware.com/blog/cost-to-build-a-carpooling-app-like-blablacar>

priority of Duke's administration. The app will help meet Duke's goal of carbon neutrality by 2024, a benefit that can only be achieved with some financial sacrifice.

Also, as shown in a study done in Los Angeles analyzing student's transportation behaviors, increasing student use of other alternate modes of transportation, such as biking, walking, or public transit, actually increases carpooling as well.²⁵ This result is surprising, but also encouraging. According to this study, if Duke could help students use public transportation or other alternate modes of commuting to campus, then they would be more likely to carpool more as well, further decreasing emissions. Thus, initiatives to increase Duke students' use of alternate modes of transportation to campus (not including carpooling) could also be paired with this carpooling app to further decrease student emissions.

²⁵ Zhou, Jingping. "Sustainable commute in a car-dominant city: Factors affecting alternative mode choices among university students" *Transportation Research Part A: Policy and Practice* 46.7 (2012). 1013-1029.

Conclusions

Our carpooling application has the potential to significantly reduce student transportation-related emissions on Duke's campus. If 50% of students who live off campus join and use the app weekly, the emissions reduction would be 13%. Considering transportation-related emissions have risen 9% since the baseline, this would be an important step towards Duke's goal of carbon neutrality by 2024. With approximately 80% of survey respondents somewhat to very interested in a carpooling application, we are fairly confident that we could achieve 50% use of the app. Through meetings with the administration and a focus group, we have created an app that meets the needs of the Duke administration as well as students. We hope that Duke University will choose to develop our app and allow students to reap the social and environmental benefits of carpooling.

Appendix

Appendix A - Survey Questions

You are invited to take part in a research study conducted by a Bass Connections project team comprised of Sofie Alabaster, Aiden Muhr, Francois Chabaneix, Pranav Lakhina, and Audrey McManemin.

The purpose of this study is to analyze how students travel to and from campus when living off-campus and to gauge interest for a mobile carpooling app.

Participation in the study involves completing a survey that will ask you questions about you, such as where you live and how you travel to and from campus every day. You will also be asked questions about a mobile carpooling app.

The total time for completing the survey should not exceed 2 minutes.

If you choose to participate, your name will not be linked to your survey responses at any time. De-identified information may be made public or used for future research purposes.

The research will not benefit you personally. We know of no risks resulting from participating in the study.

If you have any questions about the group or the research, feel free to email any of the names listed above.

If you are interested in taking the survey, please click to the next screen.

- I consent
- I do not consent

Q1 What year are you?

- Junior
- Senior
- Graduate Student

Q2 Do you live on campus?

- Yes (East, West, Central)
- No

Q3 Where do you live?

- Berkshire Ninth
- Berkshire Main

- Erwin Mills
- 810 9th Street
- The Heights
- West Village
- Station 9
- The Flats
- Trinity Commons
- University Apartments
- Loft Exchange
- Solis Brightleaf
- Chapel Tower
- Campus Walk Avenue
- Belmont Apartments
- Other

Q4 How do you get to campus most of the time?

- Car (drive alone)
- Carpool (2+ people)
- Bus
- Rideshare App (Uber or Lyft)
- Bike
- Moped
- Walk
- Other

Q5 How many times a week do you get to campus by car? (Please enter a numerical value)

Q6 How interested/not interested would you be in carpooling with other Duke students to designated locations on campus and back home?

- Not interested
- Somewhat interested
- Interested
- Very interested

Q8 What would be a reasonable incentive for you to carpool with other students? (Rank)

- Better parking spot
- Reimbursement on parking pass
- Other

Q9 Where would you prefer to park? (Check all that apply)

- BC Lot
- First or Second Lot in Blue Zone
- Visitor Parking Lot (by Sanford)
- Science Drive Lot (by JB Duke)
- Gross Hall Lot

- Other

Appendix B - Focus Group Questions

1. Would you feel safe using our app? What would make you feel safer?
2. How many spots would you be willing to give up in the car?
3. Would you feel comfortable rating your friends?
4. If you are a driver, would you want to receive a request when a rider wants to carpool with you, or would you rather the person to be directly added to your car in the system?
5. How would you like to filter drivers?
6. Would you prefer the app to have a built-in chat feature or would you rather text them directly?
7. Would you be upset to always be a driver?
8. Do you feel like being a driver is a financial burden?
9. Would you rather be in a car alone or share a ride with people?
10. How far in advance would you like/ are you likely to schedule a ride?
11. Would you feel comfortable carpooling with graduate students?
12. Should riders have a rating too?
13. Would you rather the carpool app to be separate or part of the Duke Mobile app?
14. Are there any features you would like to have added?

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