Reducing Commuter Emissions at Ohio State University

ENR 4567 Capstone

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1) Executive Summary

The Ohio State University (OSU) has an estimated average of 60,000 students, faculty, and staff that commute in a personal vehicle on weekdays during the two primary academic semesters (appendix 6.1). To manage this volume of vehicles and the requisite parking spaces OSU leases the management of parking to CampusParc. In order to help OSU reduce CO_2 emissions from commuters, our project team has been tasked with identifying reduction strategies that fit within the bounds of the CampusParc concession agreement. Subsequently, our team proposes three solutions to reduce commuter emissions.

Our team's first proposal is to expand parking lot counters to applicable surface lots. This will enable commuters to identify available surface lot parking through app and website integrations. Three identified lots on campus produce an annual estimate of approximately 10 metric tons of CO_2 from commuters circling for parking spaces.

Our second proposal is to expand the campus bus service to incorporate transport between the main and branch campus locations. This would provide transport for students from outlying communities as a de facto “park-and-ride” and allow faculty that instruct at more than one location to easily travel between campuses.

Our last proposal is to adjust class scheduling to reduce the number of days commuters need to travel to campus. If one commute day per week could be eliminated about 15 thousand metric tons of CO_2 per year could be eliminated. Of the three strategies evaluated, this has by far the largest impact on reducing CO_2 emissions. In addition, this proposal increases flexibility for students and faculty with work, research, and other extracurricular activities.

2) Introduction

In response to the request for proposal by The Ohio State University (OSU) our project team has assembled this report outlining opportunities to reduce commuter-based emissions. Core objectives for emissions reduction include research and analysis of surface-lot car counters; campus-to-campus bus transit; and faculty and student scheduling and telecommuting opportunities.

Surface-lot car counters count the number of cars in a parking lot at any one time. This number compared with the total number of parking spots in each lot yields the number of empty parking spots. The idea with car counters is to display this number rapidly and accurately so that students, faculty, and staff can make parking decisions that save time, lower fuel costs, reduce congestion, and reduce CO_2 emissions.

Campus-to-campus bus transit has the potential to reduce emissions from faculty and students that commute between the various OSU campuses and their outlying areas in personal vehicles. Campus Area Bus Service (CABS) is currently a commuting option in and around the Columbus main campus. By expanding these services to include travel between campus locations, main campus congestion and CO_2 emissions may be reduced, depending on demand for such a service.

OSU offers in-person classes Monday through Friday and events throughout the week; for many students, faculty, and staff, a personal vehicle is the commuting option of choice or necessity to attend work, classes, and events. Major areas of study and individual colleges have opportunities to adjust and reduce the number of days necessary per week for in-person classes. By altering the schedule for in-person classes in a typical week, traffic congestion and overall emissions reduction can be achieved simply by requiring students, faculty, and staff to commute to campus less often.

In 2015, OSU entered into a unique parking lease agreement with CampusParc, an Australian based company, that gives full management responsibilities of all OSU parking spots, lots, and garages to CampusParc. As part of the agreement, OSU is unable to directly engage in actions that reduce the number of parking passes sold by CampusParc to students, faculty, and staff. As part of our team's research, CampusParc was contacted, who stated they are willing to renegotiate the contract in the future to perhaps allow more direct emissions reduction actions on the part of OSU (appendix 6.5); however, the scope of this report only extends to opportunities possible within the current agreement framework.

In conducting research, our team designed a transportation survey intended to fill in gaps analyzed in OSU collected transportation survey data (appendix 6.2). The COVID-19 pandemic and the cancellation of in-person classes hindered our ability to administer this survey, so instead some educated-estimations are made based on general emission data, anecdotal analysis of commuter behavior at OSU, and other already-available OSU collected survey data. In addition, benchmarking analyses of other universities with a similar size and/or car culture were performed by our team. Accordingly, the recommendations made are based on data collected by OSU, estimates and calculations made by our team, and benchmarking analyses.

We recommend that OSU expand existing parking garage utilization indicators to surface lots and begin research into scheduling opportunities that reduce the number of required commute days. We believe more data is necessary to fully analyze the efficacy of an expanded bussing program.

The team hopes our research is valuable to the university and will lead to a reduction in commuter emissions. The endeavor of this report was undertaken with a vision of a future OSU; one that is a net-positive for the state of Ohio and city of Columbus in all three pillars of sustainability: economic, social, and environmental.

3) Research

Most of the data used for our commuter emissions reduction proposals comes from OSU's internal transportation survey conducted, on average, biennially. Our team was able to gather survey data from 2012 to 2019; the 2020 survey had already been administered and results collected at the start of Spring semester, but the data was not yet compiled and available for evaluation in time to be included in this study. OSU published survey results prior to 2017 in an annual report; the survey data for 2017 and 2019 was provided in raw spreadsheet form only.

Upon analyzing gaps in OSU collected survey data our team created and planned to conduct an in person-survey at a variety of parking locations around campus. The purpose was to gather information about specific topics that past OSU's surveys did not cover. Some key data missing from previous OSU's surveys that our planned survey was designed to cover includes:

- Number of commuters that travel between OSU main and branch campuses
- Commuter attitudes toward using campus busing that would provide transport between main and branch campuses.
- Commuter attitudes toward using campus busing between OSU and other colleges or universities in the local or regional area
- Major areas of study and colleges with which most commuters are affiliated

The survey collection period was scheduled to start immediately following Spring Break 2020. Due to in-person classes being canceled considering the Covid-19 Pandemic, the in-person survey collection had to be canceled. While it may have been possible to administer the survey through email, it was concluded by our team that administering our survey in such a way would not be effective in terms of reaching our target audience and providing statistically meaningful results. Instead, our team focused on extrapolating results from existing OSU survey data, as well as benchmarking research.

Note: *The survey design created by the project team has been attached as a tool for future research in appendix 6.3*

3.1) Proposal #1: Surface Lot Counters

The first strategy identified by our project team is the expansion of existing informational infrastructure that OSU utilizes for parking garages. The parking garages use an integrated data collection system that translates the calculation of how many cars have entered and exited the garage into a percentage of occupancy that is displayed outside of parking garages. This information is also conveyed in real-time to users of OSU's phone application and on the CampusParc website. The idea of the surface-lot counters is to provide users the ability to make the same sort of real time, informed decisions that are available to individuals parking in garages. (CampusParc, 2020)

There is currently no system in place to convey the fullness, or utilization, of most surface lots. The OSU smart-phone application contains no surface lot utilization information, while the CampusParc website provides estimates of Carmack and Buckeye surface lot fullness. This lack of publicly available parking lot utilization data leads to additional commuter emissions because of failed attempts to find an open spot and the resulting car miles necessary to find one. Surface lot parking counters would fill this gap in the system and reduce the carbon footprint of OSU's commuters by reducing the travel necessary for commuters to secure parking. Parking lot availability information would also save time and reduce frustration when commuters are attempting to park and make it to campus activities on time.

3.1.1) Surface Lot Counter Data

Three parking lots on the main campus were selected for a physical study on commuters searching for parking spaces. The sample lots were chosen for a variety of factors including:

- Distribution of parking pass types
- Single entrance and exit for easier study
- Nearby elevated vantage points for easier study
- Locations in different regions of campus
- Locations continuously near capacity during peak time of 10am-2pm

The first lot selected is the large lot off of Coffey Rd (Lot 1) on West Campus, and includes faculty (A), staff (B), and student (C) levels of parking spaces. The second lot is the Northwest Stadium Lot (Lot 2), which is a middle size comparatively, is near central campus, and only has C level parking. The third lot (Lot 3) is comparatively the smallest, is on the fringe of the medical campus and includes A and B level spaces. These lots are illustrated on a campus parking map excerpt in Figure 3.1. Conveniently, the total number of parking spaces in these lots is approximately 1,000 (CampusParc, 2020)

Figure 3.1: OSU Parking map with target lots circled.

Two days before parking lot evaluations were to begin, OSU Columbus campus shut down due to COVID-19. Exact measurements of vehicles entering and circling the lots were unable to be obtained. The original rough assessment of the parking lots, via eyewitness accounts, enabled our team to make estimates of the quantity and frequency of commuters entering the lots, as well as those unable to find a parking space. While the values presented below are only back-of-the-envelope estimations, they are within an order of magnitude of exact data and provide enough statistical relevance to be taken into consideration for a recommendation.

From the initial site evaluations conducted at 10am on a typical Thursday during Spring semester, it was estimated that one car entered Lots 1 and 2 every thirty seconds. Of these commuters about half of them could not locate a parking space after circling the lot and then travelled elsewhere in search of parking. Some commuters circled the lot numerous times; some commuters sat and idled in their vehicles waiting for someone walking into the lot to go into a car and vacate a space; some commuters travelled up and down numerous rows in the parking lot and travelled a distance far greater than the loop estimates used below. The project team believes the values chosen are extremely conservative and represent the lower bound of vehicles and the distance travelled. Using the distance measuring tool within Google Maps our team was able to identify lengths of simple routes through the identified parking lots. (Google, 2020)

The shortest loop through Lot 1 totals about 1920 ft. There are a wide variety of possible travel combinations that a commuter might choose in pursuit of a parking space in this lot, but only one path was calculated. The route is identified in figure 3.2 and represents the shortest path that a commuter would take to give themselves a sightline of the most parking spaces.

Figure 3.2: Aerial view of Lot 1 and highlighted circling loop.

Two possible sample routes for Lot 2 are given in figures 3.3 and 3.4, with the distance being 0.23 miles and 0.16 miles, respectively. During peak parking hours lot 2 is generally full, with most commuters being observed to take at least one loop of the lot, with the route in Figure 3.3 being the typical case.

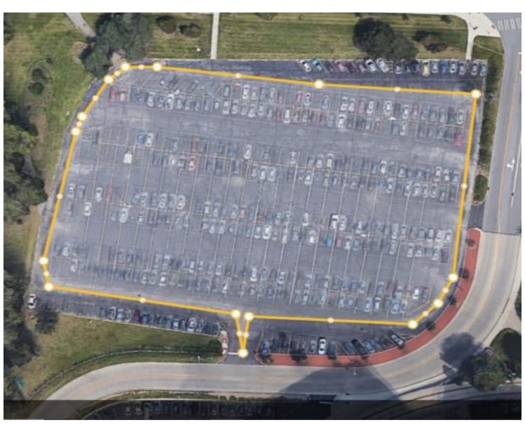

Figure 3.3: Aerial view of lot 2 long loop

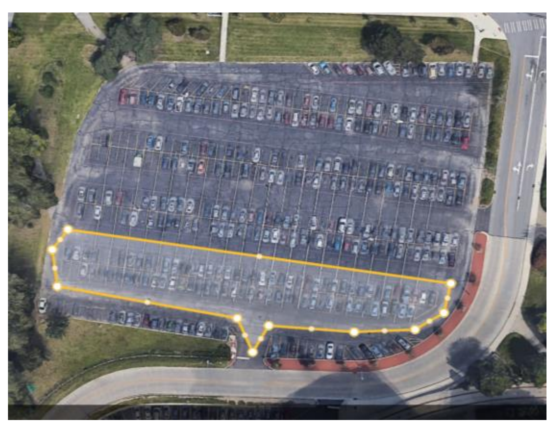

Figure 3.4: Aerial view of lot 2 short loop

The longest and shortest possible loops for lot 3 are given in Figures 3.5 and 3.6. The loops are 0.11 miles and 0.1 miles, respectively. Due to its size, this lot is almost always full.

Figure 3.5: Aerial view of Lot 3 Long Loop

Figure 3.6: Aerial view of Lot 3 Short Loop

3.1.2) Surface Lot Counter Calculations

Using the estimated loop calculations above, the minimum distance a commuter that failed to find a spot in lot 1 would travel is 0.36 miles. If one commuter fails to find a spot every minute of the peak 4-hour period, that totals 240 failed attempts to park. The total distance traveled within this single lot in the given timeframe would be 86.4 miles. Using the EPA estimate of 404 grams of CO_2 per mile, unsuccessful parkers create 34,905.6 g, or about 35 kg of CO_2 in a single day in this single parking lot. (Ranges for the estimated data in this section can be found in appendix 6.7) (US EPA, 2016)

In Lot 2, the average distance a commuter travels before finding parking is 0.2 miles. Using the same estimate of 240 failures per 4-hour period, the total distance commuters travel in this single lot in the given timeframe is 46.8 miles. At 404 grams of CO_2 per mile, the total estimated CO_2 that is generated is 18.9kg, of CO_2 during peak hours each day.

Applying the same estimations to Lot 3's average distance travelled of 0.11 miles translates to 25.2 miles. This produces approximately 10.2 kg CO_2 during peak hours for commuters circling. For the entire year, this translates to 1.63 metric tons of $CO_{2.}$ This number may be an exaggeration due to the small size of the lot and the ease with which commuters can see the fullness from the road. Nonetheless, we assert that even this number is likely conservative when considering the distance travelled on surface roads to look for parking, even if the search is accomplished from the road.

There are approximately 160 fully attended (Autumn and Spring semester) academic days at OSU. As such, over the course of the primary two-semester academic year these three lots alone produce a conservative average of 10,236 kg, or 10.2 metric tons of CO_2 from approximately 25,344 miles travelled in search of parking during peak hours. As mentioned, what is not included in this estimation is most of the additional distance the commuter travels across surface roads to go from lot to lot.

It would not be statistically sound to apply the estimates from these three parking lots across the universities' entire 24,000 surface parking spaces. The distance a car travels in search of parking in each lot is different. Some of the parking lots never reach capacity and others are near capacity well beyond peak hours. Nonetheless, it is reasonable to assume that half of these spaces (12,000) are in lots that are near capacity for at least four hours on weekdays. With this as the case, the savings could be on the order of 12 times the 10.2 tons per year if the 1,000 spots in Lots 1, 2 & 3 are scaled up. Furthermore, as noted, there are additional CO_2 savings from vehicles no longer needing to travel surface roads in order to find a spot to park. Also, it is reasonable to assume reductions in traffic congestion which in turn reduce fuel use and emissions for *all* vehicles parking during these peak periods. Thus, many times more than 10 metric tons of CO_2 per year can be saved by improving the efficiency of parking in surface lots.

3.1.3) Surface Lot Case Study

3.1.3.1) Ohio State University

One of the best case studies to understand the potential value of surface lot counters is the OSU parking garage counter system. Each parking garage on campus already has their own lot counter to show drivers how full the garage is. This information is also shown on the OSU app and a website that commuters can check before leaving, enabling them to know which garages have empty space so they may plan accordingly. This is particularly useful when there are highly attended events such as football games in the Fall. In real time, commuters know which garages have available space, instead of trying to navigate campus and "hope" the garage they are going to has room. People going directly to locations they know have available parking also cuts down on traffic, and therefore CO_2 emissions. As such, there would likely be similar or even greater value of installing lot counters into the surface lots around the campus.

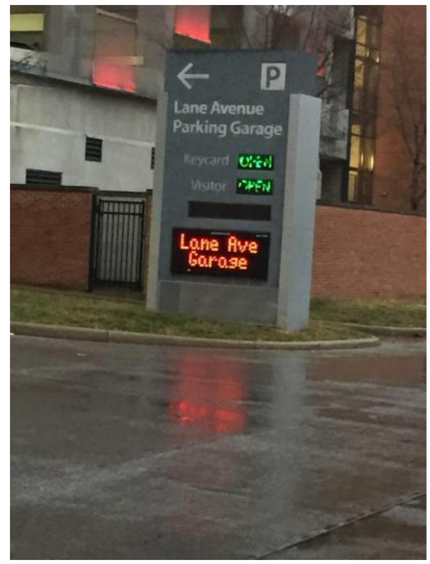

Image 3.1: Existing garage fullness display

3.2) Proposal #2: Regional Campus Busing

Students and faculty are sometimes required to travel between branch campuses and the main campus. This can create a significant amount of carbon emissions due to the distance between the campuses and the amount of people that make the trips. One way to reduce these emissions is establishing bus lines that travel between branch campuses and the main campus. Students and faculty could drive to their usual campus and park their car, then they could take a bus to and from the campus they desire to visit. This bus system would give the students and faculty that must travel to other campuses a new option to reach the other campus, one that potentially reduces net OSU commuter emissions.

While our team simply did not have the necessary data to estimate the amount of reductions associated with an inter-campus bus shuttle service, it is most likely less than the 3% reduction in commuter emissions found in the SDSU study (see discussion in next section). This is because the SDSU study evaluated increased bus ridership among commuting trips to and from campus, not just campus to campus shuttles. A 3% reduction in OSU commuter emissions (approximately 80 Thousand Metric Tons per year when classes are in session) would translate into about 2 thousand metric tons of CO_2 savings per year, so it is likely that campus-campus shuttles would reduce CO_2 by less than 1 thousand tons.

Notably, the cost of this carbon reduction strategy would likely not be significant providing OSU can allocate some of its current buses to the new branch campus bus lines. In this case, the only additional costs would be for the extra fuel and driver pay. However, if OSU must buy new buses for the branch campus lines, then the cost could go up considerably. The cost of new transit busses is over $250,000 each, and several will be necessary to provide adequate service coverage for students and faculty traveling between campuses. (CDOT, n.d.)

3.2.1) Regional Campus Busing Case Study

3.2.1.1) San Diego State University:

In 2017, San Diego State University (SDSU) released their Climate Action Plan in which they analyzed a variety of options to become more sustainable and reduce greenhouse gas emissions. Of relevance to this report, one option analyzed was commuter travel emissions. SDSU came up with six commuter emissions reduction strategies and estimated the impact each strategy would have on their overall transportation emissions. One strategy was to expand the use of public transit. SDSU estimated that 10% more people will use transit if the option is provided and promoted. This increase in ridership would reduce overall SDSU commuter emissions by 3%, as previously mentioned in section 3.2. Public transit utilization is a core strategy to reduce commuter emissions for universities because of its ease of implementation and track record.

What makes SDSU's evaluation relatively unique is their estimate of the CO_2 reductions from a specific public transit policy. While these findings indicate that public transit does not have a very large direct impact, it is still relatively significant and does not include other direct and indirect sustainable benefits of implementing such a policy, like facilitating productivity during the commute. Importantly, it demonstrates that SDSU is actively trying to become more sustainable and reduce the amount of driving that students, staff, and faculty are doing around and to campus. (SDSU, 2017)

3.3) Proposal #3: Course Scheduling and Telecommuting

The course scheduling and telecommuting proposal aims to reduce commuter emissions by decreasing the amount of days that faculty, staff, and students are required to commute to campus. The target of this proposal is an upgrade to the OSU online workplace and learning infrastructure; this will lead to more options of working remotely and promote flexibility for students and faculty in balancing family, work, school, and extracurricular activities.

3.3.1) Calculations

Based on data obtained from the 2017 and 2019 OSU transportation survey, average percentages of each classification (faculty, undergraduate, etc.) of commuter was calculated in Table 1 (all tables mentioned in section 3.3.1 are in appendix 6.1). In addition, using data from the same years, the average length of commute was calculated in Table 2. Using data from Tables 1 and 2, as well as published information on the number of faculty, staff, and students on all OSU campuses, the total number of commuters per classification was calculated in Table 3 column 2, as well as the overall total of 103,682 commuters. According to 2019 survey data, 59.15% of commuters commute in a personal vehicle, bringing the overall total of 103,682 down to 60,690 personal vehicle commuters. Using data from Table 1 and the total number of personal vehicle commuters our team was able to calculate Table 3 columns 3 and 4, indicating the total number of personal vehicle commuters per classification. Combining this data with Table 2 data yields Table 4; according to this calculation the cumulative average number of miles commuted on any given school day by personal vehicle commuters to all OSU campuses is 1.2 million miles round-trip, or an average of 20 miles per commuter. At an average of 404 grams of CO_2 emitted per mile, this means that on the average school day OSU personal car commuters emit 242.5 metric tons of CO_2 on their way to campus. Round trip this doubles to 485 metric tons of CO_2, per day. With approximately 160 school days (i.e. weekdays) in fall and spring semester, 485 metric tons per day translates to approximately 78 thousand metric tons per year. 160 school days equates to 32 “weeks” (Monday-Friday). By reducing the average number of commute days by one per week, or in other words reducing the overall number from 160 to 128, the school could save approximately 16 thousand metric tons of CO_2 emissions per year. All final emissions savings calculations are available for analysis in Table 5 below. (appendix 6.1) (US EPA, 2016) (OSU, 2020) (OSU, 2020)

Total Miles Per Day (Round Trip)	Emissions Per Mile in Grams	Emissions Per Day in Metric Tons	Emissions Per Year with 160 School Days in Metric Tons	Emissions Per Year with 128 School Days in Metric Tons	Savings with Scheduling Changes Reducing School Week from 5 to 4 Days (160 overall to 128) In Metric Tons
1200297	404	485	77587	62070	15517

Table 5: Reduced commute days calculations summary

3.3.2) Scheduling and Telecommuting Case Study

3.3.2.1) San Diego State University:

As noted in a previous section, San Diego State University (SDSU) is one the few universities that has started to take proactive steps to reduce commuter emissions. In their 2017 Climate Action Plan they analyzed potential strategies that could reduce commuter emissions. One of the strategies they evaluated was increasing the amount of telecommuting options for students, staff, and faculty. They estimated that if people could telecommute once per week that it would cut 21% of their transportation related emissions. Out of the six strategies SDSU considered to reduce commuter emissions in their report, telecommuting had the highest projected reduction in emissions. The next highest option was to make students live on campus for two years instead of one, (which OSU has already implemented) and that was predicted to reduce commuter emissions by 11%. Based on the SDSU study, telecommuting will likely be the most important strategy for reducing OSU commuter emissions. This is consistent with the approximate calculations found in Section 3.3.1.

3.3.2.2) University of Illinois Chicago

The University of Illinois Chicago (UIC) has also started the process of reducing commuter CO2 emissions. Like SDSU, their primary strategy to reduce emissions is to decrease the number of days on campus for students, staff, and faculty. Though they do not have as precise of an emissions reduction forecast as SDSU, they do foresee a significant reduction in their commuter emissions once they have the technical capabilities to increase their capacity for online learning, working, and meeting. UIC cites the need for an increase in “promotion of existing technology, and improved data collection and reporting” (UIC, 2020).

4) Summary

Despite being unable to conduct surveys due to OSU campus closures in response to Covid-19, the project team was still able to estimate emission reductions from two of the three proposals utilizing analyses of existing survey data, in-person anecdotal accounts, and secondary information sources. In sum, it was found that the amount of CO_2 reduction varies significantly across each proposal as well as the level of complexity and cost of implementation, with scheduling and telecommuting opportunities projecting the largest reduction in CO_2 and lot counters being the least complex and costly to implement

4.1) Lot Counters Summary

Lot counters in the surface parking lots would help reduce overall short-term commuter emissions. The CO_2 emission savings from implementing lot counters in the three lots analyzed in section 3.1.2 is approximately 10.2 metric tons per year. Conservatively, we assert that across the entire university parking system emission savings as a result of lot counters is approximately 122.4 metric tons per year. With lot counters utilization information being readily available, people could go directly to the lots that have open parking spots instead of emitting more CO_2 looking for a spot. This not only reduces their own personal carbon emissions, but it also helps with the alleviation of traffic around the campus. One of the positive attributes of the lot counter proposal is that OSU is already using this technology; each parking garage has a lot counter display outside indicating capacity. This information can be seen from the road and on the OSU app. People can see which garages are full before arriving on campus so they can go directly to the garages that have available space. While the impact on commuter emissions with lot counters is significant, it is not substantial relative to overall OSU emissions; Nonetheless, the technology is already in-use on campus and would only need to be expanded to achieve the intent of our proposal.

4.2) Regional Bussing Summary

Students and faculty frequently travel between branch campuses and the main campus at OSU. This amount of travel can create a significant amount of emissions because of the number of branch campuses and the distance between them and the main campus. Depending upon demand, a shuttle or public busing system running from the branch campuses to the main campus could reduce commuter emissions. Instead of people individually driving between campuses, they could take a shuttle or bus and leave their vehicle behind. OSU does not currently have transit lines for such a system in place, so they will either need to reallocate current buses in the fleet or purchase new buses. New buses can be incredibly expensive, generally costing around $250,000 each. To implement such a system would require multiple buses. Looking at other universities and general public transportation trends, buses do not cause a significant reduction in greenhouse gas emissions from commuters due to lack of ridership. As a result, OSU should encourage and promote the use of the Campus Area Bus Service (CABS) and Central Ohio Transit Authority (COTA) systems as a prerequisite to this proposal. Due to a lack of data on potential ridership we were not able to calculate potential CO_2 emission savings by offering bussing services between campuses.

4.3) Scheduling and Telecommuting Summary

With upwards of 60,000 individuals commuting to the OSU main campus on any given day, there is a potential to greatly reduce commuter emissions by reducing days required to travel to campus. While some employee positions at OSU are not possible or desirable to convert to telecommuting, there is much OSU can do to reduce non-essential personnel travel from day to day. To accomplish these ends the university can: promote more online courses, adjust scheduling within majors so that courses fall on alternating days, encourage or require instructors to conduct remote lectures one day a week, or simply declare that a certain day of the week there will be no in-person classes (akin to implementing a 4-day work-week).

While this is not a minor undertaking, our team asserts that the current situation with COVID-19 causing a campus-wide shutdown of in-person classes can be viewed as a proof of concept. With short notice and the health and safety of thousands of students and staff on the line, OSU was able to shift into entirely virtual instruction mode. If the university can perform this amazing feat of flexibility under an emergency basis, it also has the capability to implement a similar driving reduction framework with planning and consideration that preserves the university experience while reducing CO_2 emissions.

5) Conclusion

Reducing commuter emissions at OSU will be no easy task given how the parking concession agreement is structured. According to the agreement, OSU is not able to directly negatively impact the number of parking passes sold by CampusParc. It was uncovered during research that administrators within CampusParc are open to renegotiating certain aspects of the concession agreement that may be limiting OSU's ability to address commuter emissions, but overall, our research was confined to the parameters of the current agreement. In addition to CampusParc's openness to renegotiating the agreement, CampusParc offered three other suggestions that may be worth consideration for future research studies. A copy of an email with the above information is attached in appendix 6.5. Regardless, there are both short and long-term opportunities to reduce commuter emissions while operating within the bounds of the original concession agreement.

In the short-term, surface lot counters will offer a reduction in emissions utilizing relatively low investments of time and money. They will also facilitate lowering traffic congestion and commuter frustration that can result from the inability to find an open parking spot. Commuters can use already existing systems that they are familiar with to help identify available parking. Due to ease of implementation, positive externalities, and low-cost relative to other options, the project team recommends OSU begin working with CampusParc to expand existing lot counter infrastructure in garages to include suitable surface lots.

Using public transit to take students and faculty from branch campuses to the main campus has the potential to reduce CO_2 emissions and traffic congestion. Setting up new transit routes can be achieved at a relatively low cost if current/past busses can be repurposed and is also possible to achieve in a relatively short time frame given existing processes and training infrastructure on the main campus. Unfortunately, the project team was not able to obtain data on potential ridership or commuter attitudes towards expanding campus bus services, which would indicate demand for such an expansion. Due to this lack of data, it is not recommended that OSU consider this option until further research is conducted and data collected. However, given a high enough demand, we believe OSU can benefit from such a program.

A relatively long-term solution that can help eliminate a significant amount of commuter emissions is a reduction in the amount of days students, staff, and faculty are required to commute to the various campuses. Our teams original plan for this strategy was to identify individual major areas of study and colleges that have the most commuters, then focus on how their advisors, students, and faculty could craft their schedules to reduce the number of days requiring their presence on campus. However, exact data necessary to identify which majors or colleges were responsible for the largest number of commuters was unable to be obtained. Nonetheless, citing calculations from OSU collected survey data and benchmark analyses of other universities programs, our team concludes that this concept would result in a substantial reduction in commuter emissions. This option will likely take several years to develop and may result in indirect costs for OSU despite being relatively low-cost in and of itself. In addition to lowering emissions, as reported by our fellow ENR 4567 students in a separate research project, a program such as this also has the potential to increase the happiness and productivity of students and faculty (appendix 6.8).

6) Appendix

6.1) Name: "Commuter Emissions Savings Data.xlsx"

- Sources: 2017 and 2019 Ohio State Transportation Survey Raw Data and 2017 and 2019 Master (Appendix 6.2 below)
- Each table builds upon each other for calculations pertaining to emissions savings in the scheduling options objective.

6.2) Name: "2017 and 2019 Master.xlsx"

- Sources: 2017 and 2019 Ohio State Transportation Survey Raw Data
- The master contains all questions from the 2017 and 2019 Ohio State Transportation Survey Raw Data that the group believed to be relevant to the objectives of the project.

6.3) Name: "Reducing_Commuter_Emissions_At_The_Ohio_State_University.docx"

- Source: Gaps analyzed in the 2017 and 2019 Ohio State Transportation Survey Raw Data
- We hope this set of questions will be useful to future commuter emissions reductions efforts

6.4) Name: "CTPP3_StateOfTheSystem_20200116.pdf"

- Source: CampusParc
- This information was used for some images as well as a general reference.

6.5) Name: "EEDS capstone CampusParc feedback_contact.docx"

- Source: CampusParc
- This information conveys CampusParc's willingness to renegotiate the terms of their contract with Ohio State in order to allow for more direct emissions reductions targets.

6.6) Name: "concesion_agreement.pdf"

- Source: OSU and CampusParc
- This information conveys the inability of OSU to directly reduce the number of parking passes sold as part of their parking concession agreement with CampusParc

6.7) Name: "Ranges for Section 3.1.2.pdf"

- Source: In-person analysis of surface Lots 1, 2, and 3
- This information is here to preserve statistical significance. The numbers given in the text are averages of these ranges.

6.8) Name: "1a2columbuscorptransportationmanagement_telecommuting.docx"

- Source: Unpublished Ohio State University ENR 4567 Capstone research project (draft)
- This report provides collaborating evidence of the benefits of working from home

7) References

Google Maps. (n.d.). Google Maps. Retrieved April 12, 2020, from https://www.google.com/maps/@40.0007943,-83.02554,339a,35y,270h/data=!3m1!1e3

HR Statistics and Reports—Human Resources at Ohio State. (n.d.). Retrieved April 14, 2020, from https://hr.osu.edu/services/statistics-reports/

OSU Statistical Summary. (n.d.). Retrieved April 14, 2020, from https://www.osu.edu/osutoday/stuinfo.php#enroll

Overview of transit vehicles. (n.d.). [Folder]. Colorado Department of Transportation. Retrieved April 14, 2020, from https://www.codot.gov/programs/commuterchoices/documents

SDSU Climate Action Plan 2017.pdf. (n.d.). Retrieved April 14, 2020, from https://sustainable.sdsu.edu/_resources/files/SDSU%20Climate%20Action%20Plan%202017.pdf

STRATEGY 3.0 Reduced Transportation-Related Emissions | Sustainability | University of Illinois at Chicago. (n.d.). Retrieved April 14, 2020, from https://sustainability.uic.edu/plans/caip/strategy-3/

US EPA, OA. (n.d.). *Household Carbon Footprint Calculator* [Data and Tools]. Retrieved April 12, 2020, from /ghgemissions/household-carbon-footprint-calculator

US EPA, OAR. (2016, January 12). *Greenhouse Gas Emissions from a Typical Passenger Vehicle* [Overviews and Factsheets]. US EPA. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

Welcome · CampusParc at The Ohio State University. (n.d.). Retrieved April 12, 2020, from http://osu.campusparc.com/?sfvrsn=67