Computing for Active Transportation:
Building an Air Quality Monitor and Developing a Walking School Bus Routing Program

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ABSTRACT

The Active Transportation Research team at Harvey Mudd College spent the summer of 2015 researching ways to encourage students in the surrounding neighborhoods to regularly walk or bike to school. The team worked on two main projects: an air quality sensor and a program that assigns students to meeting locations for a Walking School Bus. The air quality sensor can educate students about air pollution by quantitatively measuring changes in concentrations of nitrogen dioxide and carbon monoxide in the air. The assignment program was able to successfully assign students to a number of locations that would typically reduce the time parents spent walking or driving their children to school.

INTRODUCTION

Over the past several decades, the number of students who drive or are driven to school has increased dramatically. In 1969, 48% of students in the United States regularly walked or biked to school; in 2009, only 13% of students did so.[1] This change contributes to increased traffic and air pollution around schools which negatively impacts student health. Recently, parent opposition has been the downfall of many attempts to implement walking programs at schools; many parents are opposed to their children walking without supervision.

The Active Transportation team at Harvey Mudd College spent the summer of 2015 researching ways to get more students in the Claremont area - where the College is located - to walk to school. In order to help organizations successfully implement a Walking School Bus program, parents will have to be convinced that the benefits of walking to school outweigh the drawbacks. The team originally had three main ideas for projects to accomplish this: an air quality sensor, a walking school bus routing program, and a bike counter. The air quality sensor has been designed to be assembled by students and used to educate them about air pollution. The walking school bus routing program was created to help organizations start a walking school bus at their schools by automatically assigning students to meeting locations around the school. Ultimately, the bike counter was not pursued because the city of Claremont already has methods of counting bikes and there are other commercial bike counters in production.

AIR QUALITY SENSOR

Introduction

Car emissions are a major source of air pollutants that negatively impact health. Among the substances emitted are nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter (PM_{10}) which have been found to be correlated with asthma, cardiovascular disease, and premature death.[2] Cars and buses idling in traffic in front of schools can unnecessarily expose children to these pollutants.

The Active Transportation team hopes to educate children about the effects that excessive driving can have on air quality. From the air quality measurements that they gather, students will ideally realize on their own that walking to school would be beneficial for their health and the environment. The measurements will hopefully also help convince parents to take part in a Walking School Bus program to help improve air quality and therefore their children's health. Students will also be introduced to simple engineering and computer science concepts by building their own Arduino-based air quality monitors.

Previous Work

Many other groups have already made efforts to research and educate people about air pollution. For example, research done by Buonano and colleagues in Cassino, Italy indicates that the number of airborne particles around the school increases around the times when parents drop off or pick up their children from school.[3] The hope is that students in Claremont will find similar results around their schools using the sensors they build then convince their parents to allow them to walk to school.

Another project designed to educate the public about air quality is the Village Green project. Participating organizations build a park bench with an interactable screen that displays information about the air quality on a given day. Figure 1 displays one Village Green station. Currently, there are stations located in Philadelphia, PA; Washington, DC; Kansas City, KS; and Durham, NC.[4] The team considered building a Village Green station near schools in Claremont, but ultimately decided it would be too expensive. There were also concerns about the possibility of schools and parents using the information from the stations as a source of negative competition.

Figure 1: The Village Green Station in Durham, NC.[4]

Numerous other individuals and organizations have built sensors and kits that people can use to monitor the air quality around their homes. The team took a similar approach with this project by finding a relatively simple monitor to build and modify for students to use.

Methods

The team built an air quality monitor using directions for a HabitMap AirCasting monitor. This design was chosen because of its relative simplicity, low-cost, and the fact that it had instructions and contact information readily available online. Shown in Figure 2 is a schematic of the layout provided by HabitMap. As shown, the sensor is composed of four different sensors: TGS 2442 which measures CO, MiCS 2714 which measures nitrogen dioxide, TMP 36 for temperature, and HIH 4030 for humidity. All of the sensors are connected to an Arduino Uno microcontroller via a breadboard. The included Bluetooth module allows the user to transfer and view the data on the AirCasting Android application.[5]

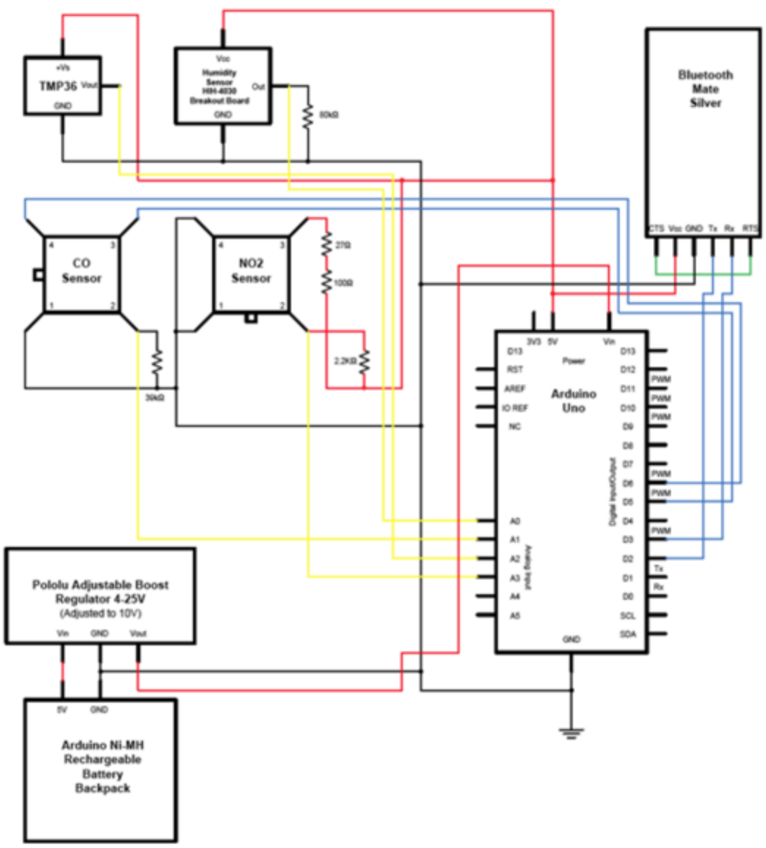


Figure 2: Schematic of the HabitMap AirCasting air quality monitor.[5]

To make the building process easier for students who would potentially build this air monitor in the future, the team made a few variations to the given instructions. For example, the instructions detail the use of a mini circuit board that requires soldering everything together.

Instead, the team decided to minimize the amount of soldering students would have to do by connecting all the components to a solderless breadboard. Furthermore, the team added a ceramic capacitor to stabilize the readings from the temperature sensor which otherwise fluctuated randomly.

Other changes that the team made were due to the availability of parts. The instructions used a MiCS 2710 nitrogen dioxide sensor instead of a MiCS 2714, but the MiCS 2710 is no longer in production. Therefore, the team used a MiCS 2714 sensor with a MiCS 2710 footprint. The team was also unable to obtain a Liquidware Lithium Backpack, so the monitor is currently powered by a laptop.

Results

Although it took longer than expected to get working, the team was able to successfully build a working air quality monitor. A user should be able to wirelessly connect the monitor to any Android device with the AirCasting app installed. However, because it took so long for the sensor to work, the team was unable to calibrate it or use it to run any actual tests. It is currently known that while the temperature and humidity sensors returns relatively reasonable values, the gas sensors are currently able to only quantitatively measure changes in the gases they quantify. To ease the building process in the future, a list of tips and suggested changes has been created. The team's assembled air quality monitor is shown in Figure 3.

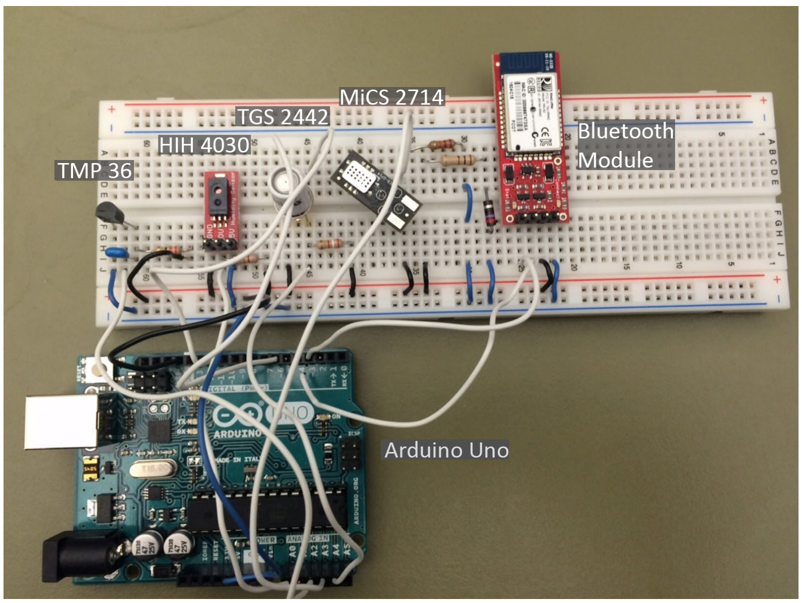


Figure 3: The completed air quality monitor.

Discussion

The air monitor still has a few limitations that prevent it from being fully usable in its intended classroom setting. Teachers would probably be reluctant to include the monitor in their curriculum if it takes several weeks to build; it is not yet clear whether the team's hints page would significantly improve the speed of the assembly process. Furthermore, the educational interface that the team intended to design this summer was not completed. This interface would have plotted the data on graphs that teachers and students could use to easily compare NO_2 and CO concentrations under different conditions. Then, the students would ideally recognize conditions that increase the concentrations and be able to brainstorm ideas on how to reduce them (i.e. cars contribute to higher concentrations of these gases, so students should walk to school more often). Although the sensors do not return accurate quantitative values, the students can still perform analysis on the changes in values.

Future Work

In order to get the sensor usable for students, there are some things that future members of the Active Transportation team should work on implementing. Currently, beyond some brainstorming questions for students (How does temperature/humidity/location seem to influence air quality? What can students do to improve air quality?), there is almost no usable educational interface. Modifications should be made to the current AirCasting application or a new app should be built so teachers and students can interface with the data. Ideally, an iOS app will be developed for iPads which are already accessible to teachers in the Claremont Unified School District.

In addition to educating students about air quality, the Active Transportation team could also create a list of important tips for teachers who are unfamiliar with circuitry or hardware. This way, students can be introduced to components such as resistors, capacitors, and microprocessors and learn what purposes they serve in a circuit.

WALKING SCHOOL BUS ROUTING PROGRAM

Introduction

Although the air monitor may help convince a number of parents that walking to school would be better for the environment and student health, they may still have concerns about student safety while walking to school. Walking School Buses (WSBs) and bike trains are groups of kids led by an adult volunteer who walk or bike to school together. Typically the students will walk to or be dropped off at a designated meeting location beforehand. Many students across the nation participate in WSBs on International Walk To School Day; at this once a year event, many school districts get sponsors from around the neighborhood and organize special WSBs with parent volunteers. However, a much smaller fraction of students walk or bike to school regularly.

Major concerns that parents have about their children walking to school include wanting to spend time with their children, traffic and stranger danger, and the belief that driving their children to school is more convenient.[6] However, while taking part in a WSB, parents would still be able to spend time with their kids while they go to the meeting location, children would not be walking or biking to school alone or unsupervised, and parents will often spend less time dropping off their kids at school making it more convenient. WSBs are also a more fun yet safe option for kids to get to school.

The WSB routing algorithm was developed for the use of WSB organizers who have successfully found parent volunteers and students willing to participate.

Previous Work

One major organization that promotes active transportation in children is Safe Routes to School (SRTS). This group helps schools get started with WSB programs by distributing funding, providing training and events for organizers, and suggesting resources and tips for creating walking routes.[7] However, most walking bus routes are currently created manually which can be tedious and not necessarily in the best location. The team hopes that the walking school bus routing program it developed will extend on the efforts made by SRTS and make it easier for schools and organizations to implement WSBs in their area by minimizing the effort it takes to create walking routes.

There are a number of Bus Routing and other similar algorithms already in use. However, these algorithms are solving problems that are different from the Walking School Bus Routing problem. For example, the school bus routing problem first addressed by Rita M. Newton and Warren H. Thomas in 1969 deals with optimizing the schedules and routes for multiple buses that visit multiple stops before arriving at the school.[8] The *Walking* School Bus Routing problem, on the other hand, entails students meeting at a one of many meeting places before going directly to the school. Each "bus stop" is not necessarily dependent on the schedule or location of the others as they might be for actual school buses.

The use of k-means clustering was also considered, but was determined to not fulfill the goals of the program. In the context of WSBs, k-means clustering would separate the students into groups based upon the location of their home and find a meeting place that is in the center of each home. However, it uses the straight line distance between points when determining the location of the meeting location, not the distance a child would walk. Furthermore, k-means clustering can put meeting locations anywhere: in the middle of roads, in someone's house, etc. It makes more sense for students to meet somewhere such as a local park.

Methods

The routing program was written in Python 3 and designed to be used by WSB organizers. When run by a user, the program takes a list of names and addresses and assigns them to one of many meeting locations. Once everyone has been assigned, a color-coded map displaying all the students and their meeting locations opens and the information is printed.

The user begins by setting parameters – specifying the name and location of their school, the furthest distance any group would have to walk, and the number of meeting places they would like to have. The number of meeting places is user specified rather than optimized by the program because organizing groups might be limited by the number of parents who volunteer to help. Then, the TkInter Python Graphical User Interface package allows the user to specify an Excel spreadsheet that is read by the OpenPyXL library and contains the names and addresses of students to be assigned. The program then uses the Google Places module to find parks near the school that will be suggested to the user as potential meeting places. Then, a map with the suggested meeting places opens and the user can add or remove any desired meeting places. Adding another potential meeting place does not necessarily mean it will be used as a meet location; doing so simply allows for the possibility of students meeting there.

Once the user is done modifying the list of potential meeting locations, the Open Street Maps API is used to find the latitude-longitude coordinates of the outer boundaries of each location. The purpose of this is because the Google Places module returns the location of a given place as a single coordinate. The distance from this coordinate to the school could be further than the furthest walking distance specified by the user which would prevent it from being considered as a meeting place when assigning students. However, especially with large parks, other parts of the park could be within walking distance as shown in Figure 4. The Open Street Maps API helps keep these potential meeting places open for consideration.

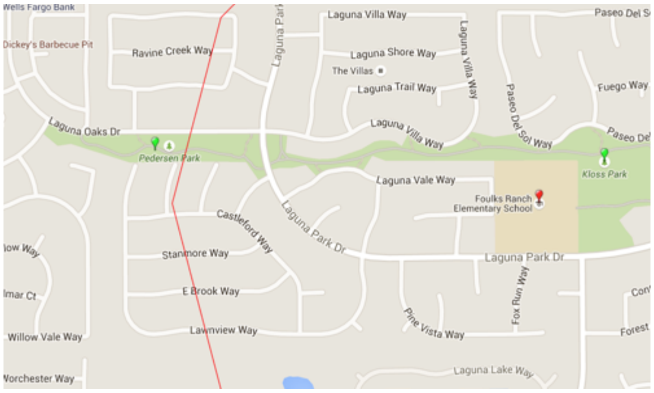


Figure 4: The green marker specifying Pedersen Park is outside of the walking distance specified by the user, but half of the park is within walking distance. Open Street Maps helps ensure that half of the park is considered as potential meeting places.

From this point in the program, there are six different variations of the routing program; all are identical in function but differ in how they assign and sort the students. There are three different ways the students are initially assigned to a meeting place: a) to the closest meeting location to their home, b) to the location that minimizes the distance the student has to walk from their home to the meeting point to the school, and c) to the location that minimizes the amount of time required it would take a parent to drop off the child on the way to the nearest freeway entrance. Assignment to the location closest to each home would likely be preferred by parents whose children would walk to the meet location alone; this method minimizes the distance the child walks without supervision. Students, on the other hand, might prefer to walk a shorter distance overall, so they would prefer to be matched to the location that minimizes the walking distance. Parents whose main concern is convenience could save some time if the meet locations are on the way to work. The user will ultimately be the one to decide what the program optimizes for.

In addition to each of these initial assignment methods, there are also two different ways students are sorted to the top *k* locations (where *k* is the number of meeting locations initially specified by the user). In one case, the program reassigns all the students not originally meeting at any of the top *k* locations to one of the top *k*. In the other case, the program takes all the students who are matched to the location with the smallest number of students and reassigns them to the remaining locations; this happens repeatedly until there are only *k* locations remaining. Theoretically, the second method should be slower to run but provide better results.

In all cases, the distance or time is found using either the Google Maps Directions or Distance Matrix APIs. The Google Maps APIs allow for the simple extraction of the desired time and distance. The Directions API returns the directions and details going from one location to another. The Distance Matrix API creates a matrix of the distances between a list of origins and destinations. Multiple calls to Directions was used over the Distance Matrix in some cases because Directions allows for the use of waypoints, a stop on the way to the final location (i.e. a park on the way to a school or freeway).

Once all the students are sorted, the program prints the top *k* locations and who meets at each. A map showing the students and meeting locations, such as the one in Figure 5, is also displayed. The students are color coded according to which location they are to meet. The HTML file that is displayed to the user is created using a wrapper module that makes it possible to utilize Google Maps' JavaScript capabilities in Python.

Alyssa K 7/24/2015 6:23 AM
Comment [1]: Only variation a) uses the Distance Matrix. Include why?

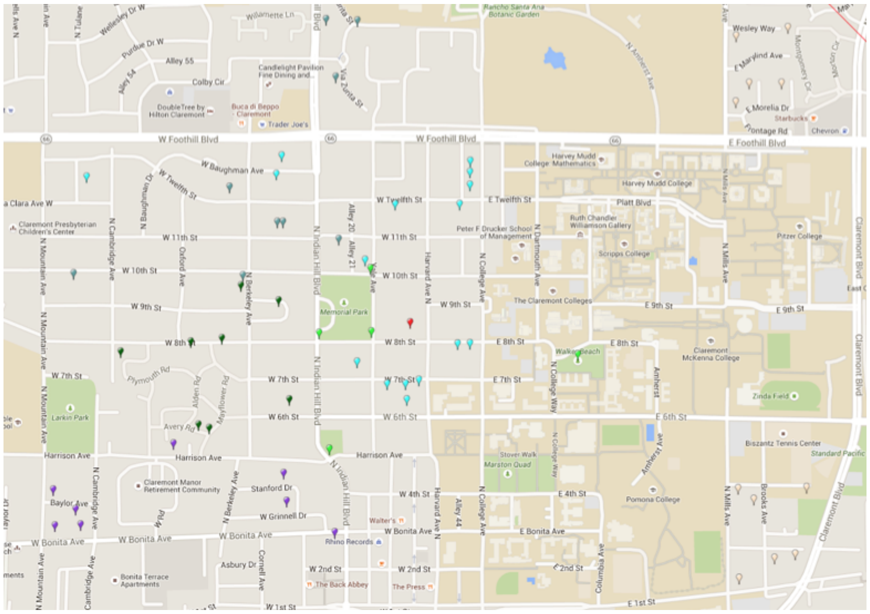
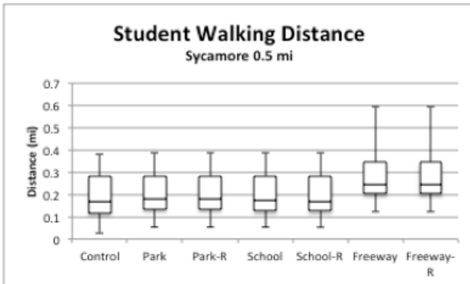


Figure 5: A map of assigned students that is displayed to the user. The school is marked in red, meeting locations are marked in lime green, and students are grouped and colored depending on where they are meeting.

Results

Each of the previously described variations of the program was run on two different schools - Sycamore Elementary and Foulks Ranch Elementary - with two different maximum walking distances - one mile and half a mile. In all cases, students were assigned to one of five different locations. Addresses were chosen from within the boundaries that determine which school children in a district should attend. In reality however, some students may live outside of these boundaries and would have to drive or walk further to get to their meeting location.

Shown in Figure 6 are graphs of the results of the tests using Sycamore Elementary, 52 arbitrarily chosen addresses, a maximum walking distance of half a mile, and five meeting locations. Graphs of the results of other tests with different parameters can be found in the Appendix.


Student Walking Distance
Sycamore 0.5 mi
Distance (mi)
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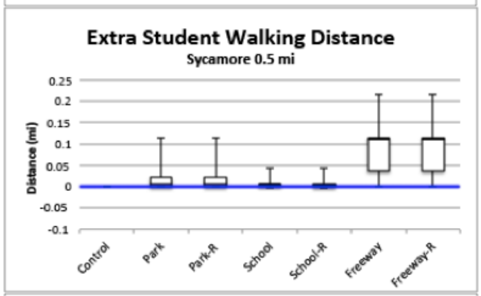
Extra Student Walking Distance
Sycamore 0.5 mi
Distance (mi)
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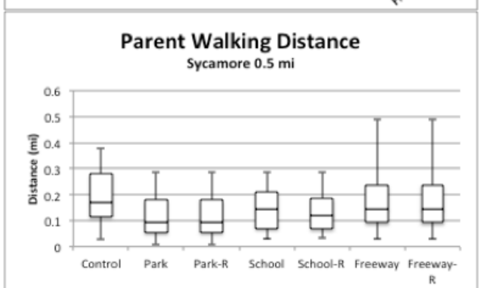
Parent Walking Distance
Sycamore 0.5 mi
Distance (mi)
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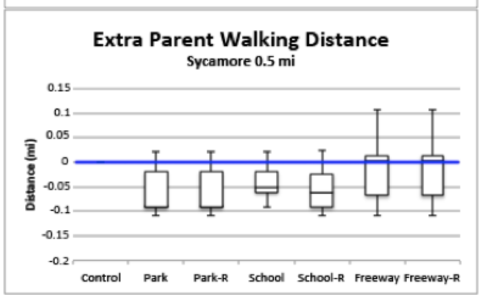
Extra Parent Walking Distance
Sycamore 0.5 mi
Distance (mi)
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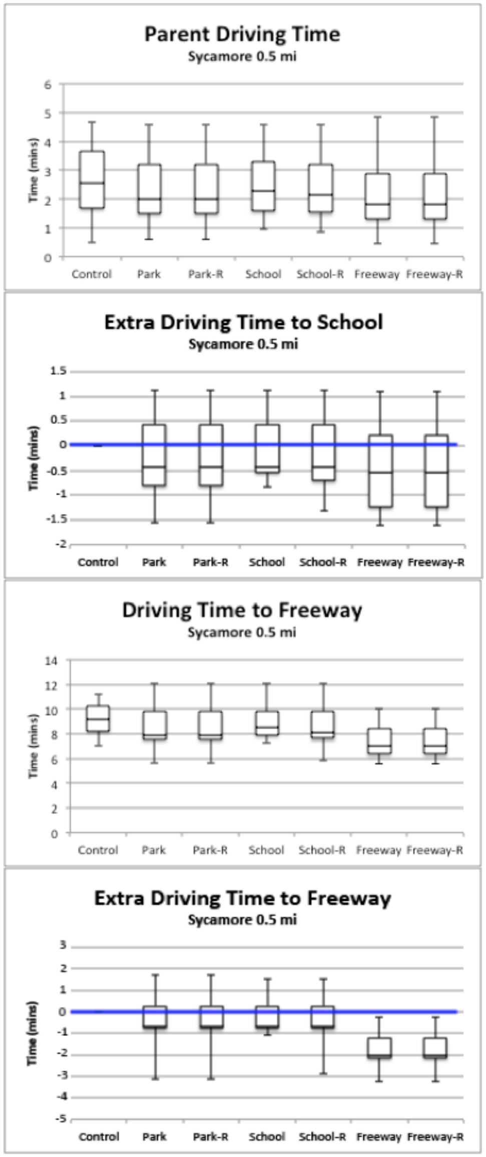


Figure 6a-h: Results of tests using Sycamore Elementary School, 52 arbitrarily chosen addresses, maximum walking distance of half a mile, and five meeting locations. Bars labeled 'Park' represent when students were assigned to the location nearest their home; 'School' when walking distance from home to school was minimized; 'Freeway' the time taken to drop the student off on the way to the freeway was minimized. Labels marked with 'R' represent the runs where students were continuously assigned until k locations remained. The blue horizontal line in the right graphs represent the control value of traveling directly from home to school or freeway.

In general, each set of graphs, including those in the Appendix, indicate that a WSB with students meeting at the locations determined by some variation of the team's WSB program would save parents time on average when compared to dropping their children off at school.

If walking from home to the meeting place then to school, students generally would have to walk a further distance than if they walked directly from home to school. This makes sense considering the path from home to school is assumed to be the shortest; any additional waypoint in between can only increase the distance walked.

Parents, on the other hand, have to walk a shorter distance to drop off their students to the meeting place on average relative to the distance they would walk to school. As expected, the majority of parents have to walk a minimal distance when students are assigned to the park closest to their home.

In all cases, parents who drop off their children at school on their way to work will typically save time, especially if students are assigned to optimize this time. Although the figure indicates a few minutes are saved, the control value does not take into consideration the time that parents spend in traffic in front of the school. Parents would likely spend less time in traffic when dropping their child off at a park which would be more convenient for them.

The performance of each variation as compared to the others is largely dependent on what each family would prefer to optimize for. Parents who hope to save time when dropping off their child on their way to work would be saved the most time when the program optimizes for that whereas parents who walk their children to school would save the most time when students are assigned to the location nearest their home.

In certain cases, the more time consuming sorting method does save parents a noticeable amount of time which suggests it would be worth taking the extra time to assign students. The extra run time would not be significant since the program is designed to be run once each time a WSB organizer wants to assign students; this would likely be about once each school year. Therefore, the team suggests using this sorting method despite the extra run time.

Discussion

There are still a number of aspects of the program that limit its functionality. Most notable is the fact that both of the Google Maps APIs have a daily request limit which could limit the number of students that can be assigned each time the program is run. They also have a rate limit which is a major reason why the program can take a long time to run (sometimes up to ten minutes in test runs).

Another major limitation of the current program is that it is unable to assign students by optimizing for different things. In other words, it is unable to assign half of the students to the location closest to their home while the other half is assigned to minimize freeway distance.

Furthermore, Open Street Maps' database of park boundaries is not complete, so not every park around a school has boundaries that can be used when determining potential meeting locations. Currently, if no boundaries for a location are found, the program will simply use the single coordinate given by Google. If a user wishes that the boundaries be used, the simplest solution would be to add them to Open Street Maps' database themselves.

The program also does not have the capability to "avoid" any specific routes when determining distance or time. In fact, it does not create a particular walking route for the groups at all; instead, it bases its suggested locations off of the route found by Google Maps. Therefore, it is up to the user or parent volunteers to use their knowledge of the area to make sure any walking routes are safe.

A problem that people might have with a WSB overall is that participation would likely require that students meet some time before school starts so there is ample time to get to school on time. While WSBs can save time for students and minimize the time parents spend on the road, it could also require that students are out of the house earlier than would otherwise be necessary. This could mean students and parents have to get up earlier or getting ready faster than before which some might be reluctant to do.

Future Work

There are a number of improvements that could be made to the program in the future to address the aforementioned limitations and improve the usability of the program. At the moment, it is not in a format that can be easily run by intended users, so it should be made more user friendly. It would likely also be helpful to create an amalgamation of the different variations that can optimize for each student individually depending on the preferences of the school or family. This could also help with the daily request limit if each variation uses its own Google developer API key.

It could also be beneficial to limit the number of students allowed to meet at each location. Sometimes, one location will have two students while another will have twenty. More students at a single location can be harder to handle for parent volunteers.

Furthermore, sometimes meeting locations are several meters away from one another. Having locations so close to each other seems pointless and should be addressed. It would probably be best to ensure each location is at least certain distance away from the others.

Finally, drawing the suggested routes on the map could be more helpful for the user to visualize even if this route is simply what Google Maps would suggest.

CONCLUSION

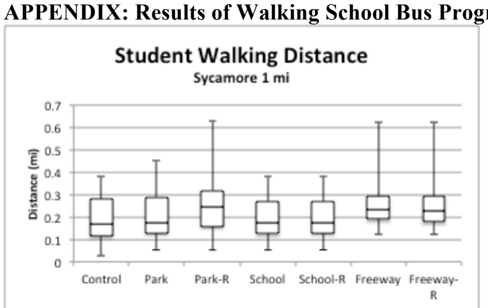
In order to help convince more parents and students in the Claremont area to walk to school, the Active Transportation team spent the summer building an air quality monitor and developing a walking school bus routing program.

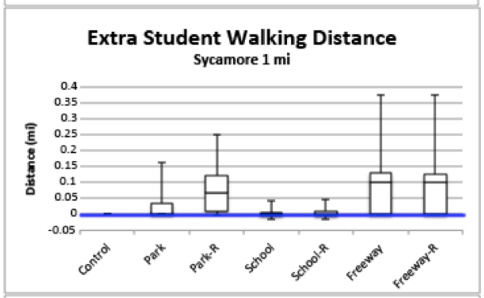
Although the air quality monitor has not been calibrated to measure exact concentrations of nitrogen dioxide and carbon monoxide in the air, it is still able to measure relative changes. Teachers would still be able to use this information in a classroom setting, and parents will be able to see how driving their children to school can affect air quality around the schools. Armed with this information, students will hopefully be able to convince their parents that they should walk to school. In the future, the team should work on an educational interface that can work with air monitor.

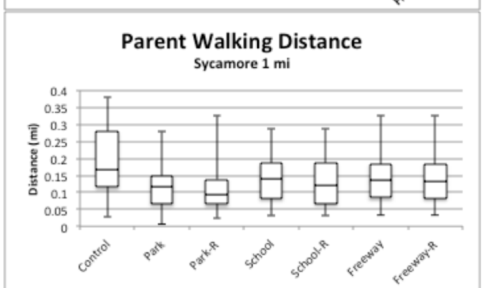
Once a number of parents have been convinced that their children should walk to school, school organizations will hopefully have more success in implementing Walking School Buses. The team's walking school bus routing automates and should simplify the execution of WSBs. The team also believes that parents would be willing to take part in a WSB because they are relatively safe, fun, and convenient. Testing has demonstrated that parents will be saved time using the WSB routing program and that the extra run time of the continuous sorting method tends to provide better results. How students should be assigned is largely up to family or school preference. Future goals of this project should be to make the program more usable for WSB organizers and implement more features.

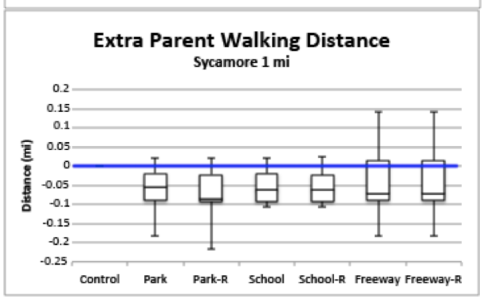
The team hopes that once either or both of these projects is usable by schools, they will have more success in convincing more students to walk to school, therefore improving student health and air quality in the area.

APPENDIX: Results of Walking School Bus Program Testing









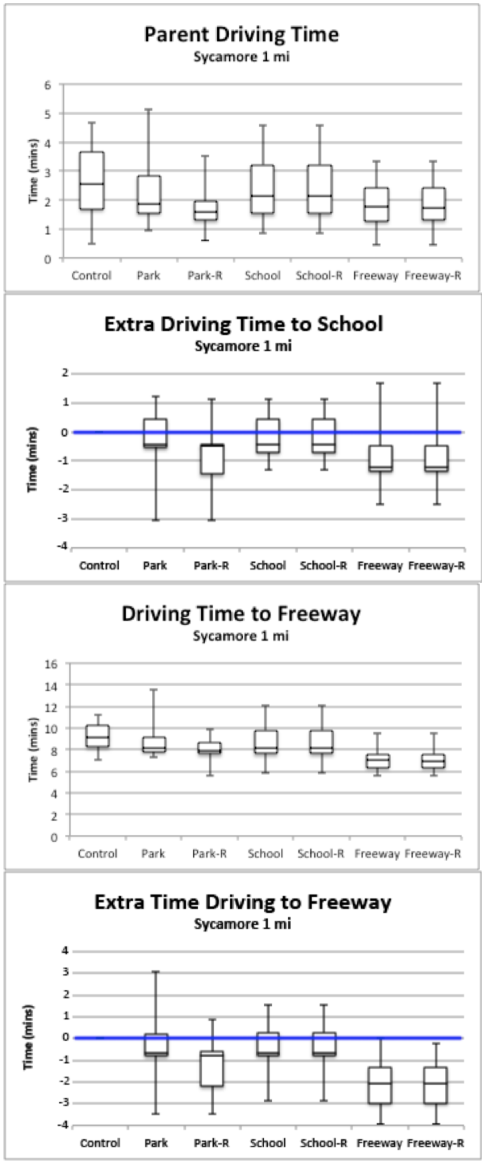
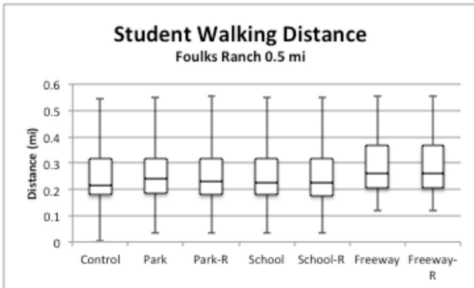


Figure 7a-h: Results of tests using Sycamore Elementary School, 52 arbitrarily chosen addresses, maximum walking distance of one mile, and five meeting locations.


Student Walking Distance
Foulks Ranch 0.5 mi
Distance (mi)
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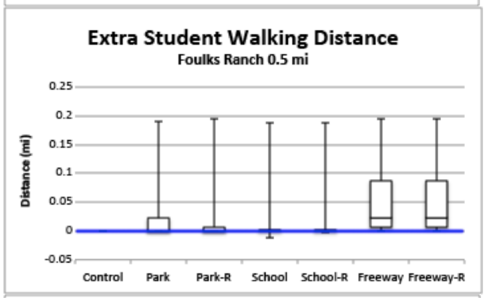
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Foulks Ranch 0.5 mi
Distance (mi)
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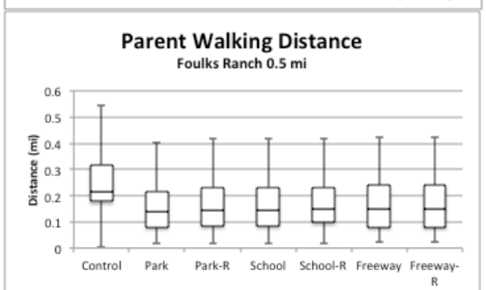
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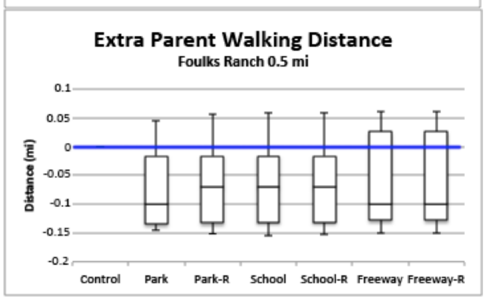
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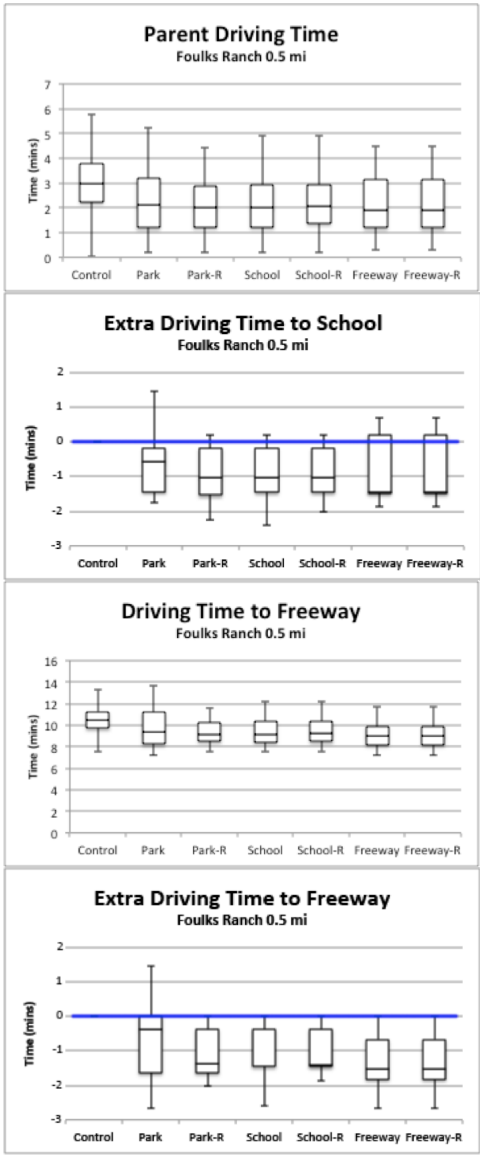
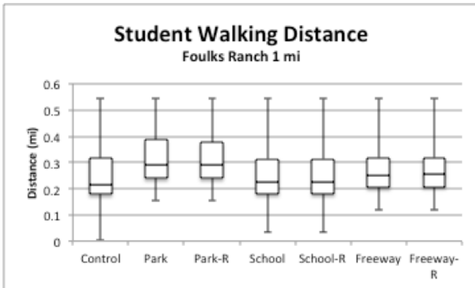
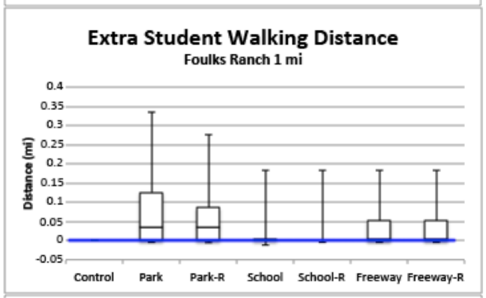


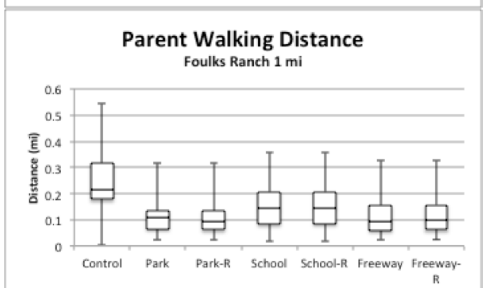
Figure 8a-h: Results of tests using Foulks Ranch Elementary School, 49 arbitrarily chosen addresses, maximum walking distance of half a mile, and five meeting locations.



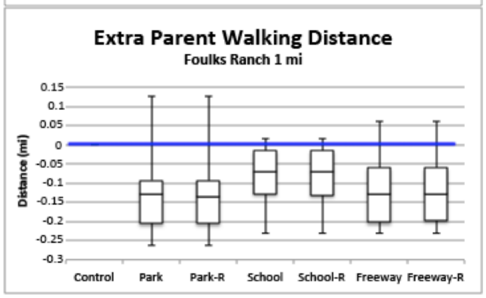
Student Walking Distance
Foulks Ranch 1 mi
Distance (mi)
0.6
0.5
0.4
0.3
0.2
0.1
0
Control
Park
Park-R
School
School-R
Freeway
Freeway-R



Extra Student Walking Distance
Foulks Ranch 1 mi
Distance (mi)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
Control
Park
Park-R
School
School-R
Freeway
Freeway-R



Parent Walking Distance
Foulks Ranch 1 mi
Distance (mi)
0.6
0.5
0.4
0.3
0.2
0.1
0
Control
Park
Park-R
School
School-R
Freeway
Freeway-R



Extra Parent Walking Distance
Foulks Ranch 1 mi
Distance (mi)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
Control
Park
Park-R
School
School-R
Freeway
Freeway-R

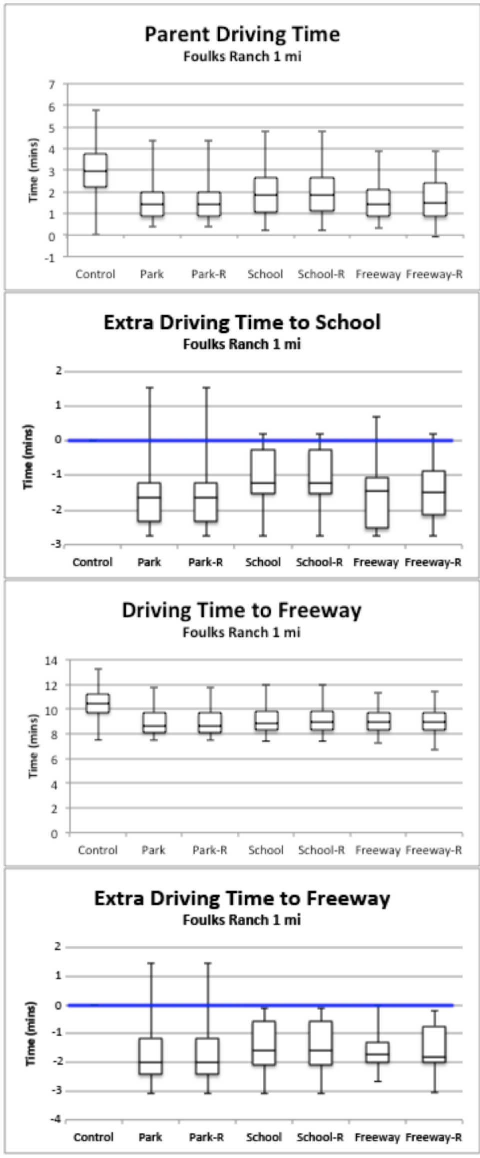


Figure 9a-h: Results of tests using Foulks Ranch Elementary School, 49 arbitrarily chosen addresses, maximum walking distance of one mile, and five meeting locations.

REFERENCES

[1] "The Decline of Walking and Bicycling." *SRTS Guide*. Safe Routes to School, n.d. Web. 15 July 2015. <http://guide.saferoutesinfo.org/introduction/the_decline_of_walking_and_bicycling.cfm>.

[2] "Near-Source Air Pollution Research." *EPA*. United States Environmental Protection Agency, 23 Feb. 2015. Web. 02 July 2015. <http://www2.epa.gov/air-research/near-source-air-pollution-research>.

[3] Buonanno, G., F. C. Fuoco, L. Morawska, and L. Stabile. "Airborne Particle Concentrations at Schools Measured at Different Spatial Scales." *Atmospheric Environment* 67 (2013): 38-45. *ScienceDirect*. Web. 1 June 2015. <http://www.sciencedirect.com/science/article/pii/S1352231012010308>.

[4] "Village Green Project." *Village Green Project*. United States Environmental Protection Agency, n.d. Web. 6 June 2015. <http://www.airnow.gov/index.cfm?action=airnow.villagegreen>.

[5] Heng, Iem, and Raymond Yap. *How to Build an AirCasting Air Monitor*. N.p.: HabitatMap, n.d. PDF. <http://habitatmap.org/habitatmap_docs/HowToBuildAnAirCastingAirMonitor.pdf>.

[6] Mcdonald, Noreen C., and Annette E. Aalborg. "Why Parents Drive Children to School: Implications for Safe Routes to School Programs." *Journal of the American Planning Association* 75.3 (2009): 331-42. *Taylor & Francis Online*. Web. 1 June 2015. <http://www.tandfonline.com/doi/full/10.1080/01944360902988794#abstract>.

[7] "National Center for Safe Routes to School." *National Center for Safe Routes to School*. University of North Carolina Highway Safety Research Center, n.d. Web. 1 June 2015. <http://www.saferoutesinfo.org/>.

[8] Newton, Rita M., and Warren H. Thomas. "Design of School Bus Routes by Computer." *Socio-Economic Planning Sciences* 3.1 (1969): 75-85. *Science Direct*. Web. 13 July 2015. <http://www.sciencedirect.com/science/article/pii/0038012169900512>.