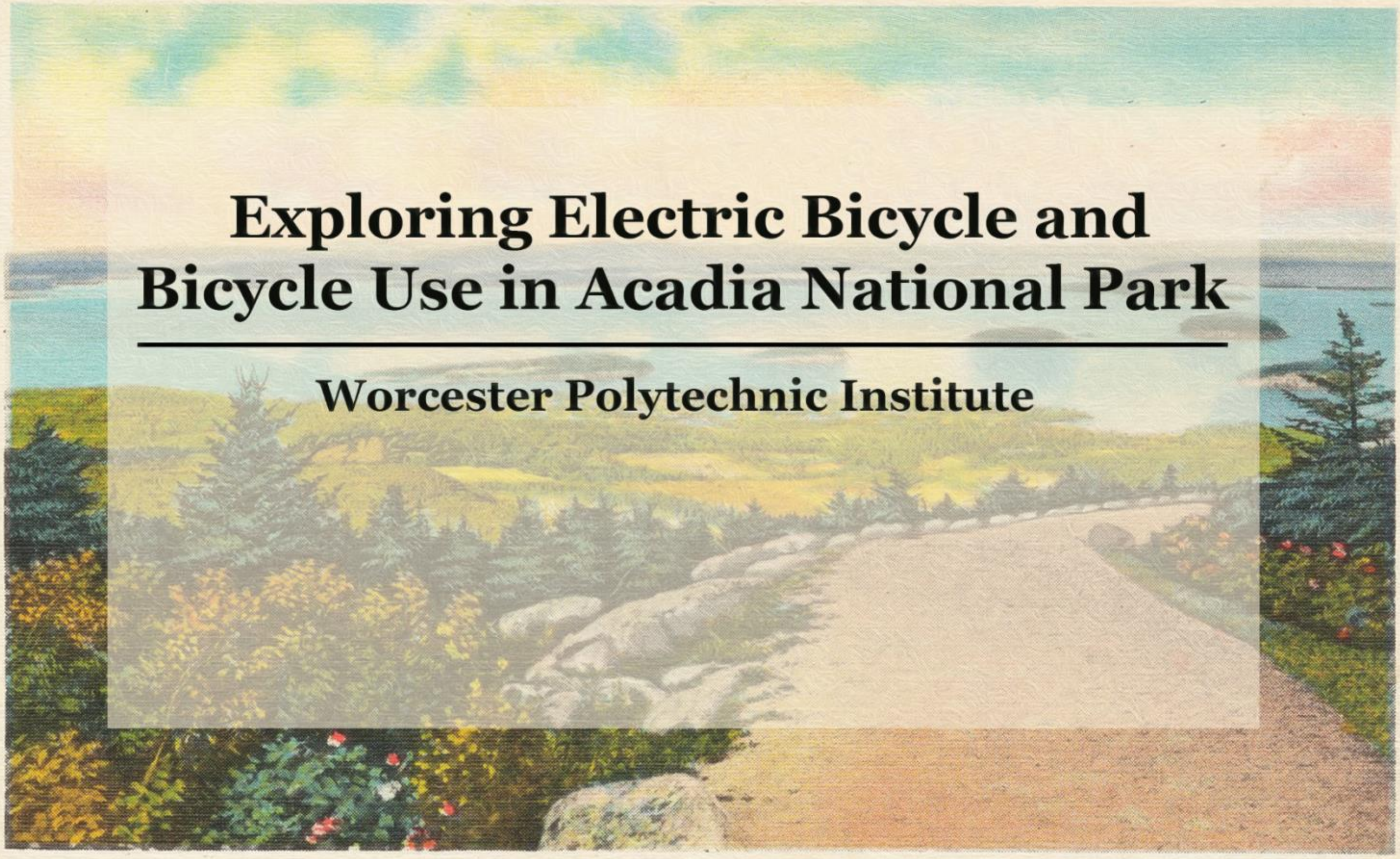
VIEW FROM CADILLAC MOUNTAIN ROAD, ACADIA NATIONAL PARK, ME 60284



Exploring Electric Bicycle and Bicycle Use in Acadia National Park

Worcester Polytechnic Institute

WPI

NATIONAL PARK SERVICE

Exploring Electric Bicycle and Bicycle Use in Acadia National Park

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

by

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Abstract

The goal of this project was to study the prevalence and behaviors of e-Bike users in Acadia National Park to determine effective policies for e-Bike use within the park. The project team monitored biking activity through webcam images in several locations within Acadia, analyzed the resulting data, and identified trends in behavior and demographics among e-Bikers and bikers. From our webcam analysis, we developed a list of recommendations for future studies to monitor biking activity within Acadia National Park.

Acknowledgements

The project received significant support and assistance to reach its goals. The project members would like to acknowledge the individuals who aided in the completion of this project.

We would like to start by thanking our valuable professors at Worcester Polytechnic Institute. First, our project advisors, Professor Frederick Bianchi and Professor Derren Rosbach, who helped us prepare for and execute our project at Acadia National Park. Professor Bianchi and Professor Rosbach also provided their support during the project by placing webcams at various locations within the park and sending us the images so we could complete our project remotely. Professor Bianchi and Professor Rosbach provided us with suggestions, recommendations, and comments on our work. Second, we would like to thank Professor Jason Davis, our social sciences professor, who helped immensely in the preparation process and identifying our goals.

We would also like to thank Dr. Abraham Miller-Rushing, the science coordinator at Acadia National Park, who gave us our research permits and suggested park employees to contact.

Finally, we would like to mention the support received from Adam Gibson, the social scientist at Acadia National Park, who guided our research associated with visitor experience and safety.

Executive Summary

Electric assisted bicycles, or e-Bikes, are becoming more common across the United States. As e-Bikes have become more popular, they have been appearing in National Parks with greater frequency (U.S. Department of the Interior, 2019). In August 2019, the U.S. Department of the Interior issued Policy Memorandum 19-01, which addresses e-Bike use within National Parks. Acadia National Park, concerned with the safety implications and impact on user experience, has had to implement policies within a short time period. Acadia National Park's current policy is to allow Class 1 e-Bikes wherever traditional bikes are permitted. Acadia National Park still lacks data regarding e-bike use needed to implement an effective policy. The goal of our project was to study the impact of e-Bike use on safety and visitor experience in Acadia National Park so that the park can determine effective policies for e-Bike use.

We formulated three objectives to reach our goal:

1) Compare Acadia National Park's existing e-Bike policy with e-Bike policies of other locations.

2) Observe and analyze the current behaviors and practices of e-Bikers and bikers in the park through webcam images.

3) Explore the feasibility of using webcams to monitor biking activity on the carriage roads.

We began the project by studying the e-Bike policies in different National Parks and comparing them to Acadia National Park's existing policy.

We then observed e-Bike users and collected data to propose recommendations for Acadia National Park to help them improve or update their current e-Bike policies. We monitored biking activity at several intersections using images from motion detecting webcams. We inputted observational data from the images into an excel spreadsheet. The data categories studied were location, day of week, date and time, incline, temperature, weather, bike type, age, gender, type of clothing worn, and helmet use. We also collected speed data using two additional motion detecting webcams along a Carriage Road.

We analyzed our collected data and identified trends in demographics and safety behavior of e-Bikers and traditional bikers. Based on the analysis, we identified four key findings.

1) *Of the 3310 bikes we observed in Acadia National Park, only 3% were e-Bikes.*
2) *Other National Parks have imposed e-Bike restrictions, but outcome assessments still need to be done.*
3) *There is a higher percentage of elderly e-Bikers in Acadia National Park than elderly traditional bikers.*
4) *The safety behaviors of e-Bikers and traditional bikers are similar.*

Our team manually counted the number of traditional bikers and the number of e-Bikers captured on the webcams to assess the ratio of traditional bikers to e-Bikers in the park. Of the 3310 bikes we observed, only 115 were identified as electric. This corresponds to approximately 3% of bikers observed on the webcams utilizing electric bikes.

We compared Acadia National Park's e-Bike Policy with e-Bike policies of 45 other National Parks. We found that 48% of these National Parks imposed additional restrictions on e-Bike use. These additional restrictions include class restrictions, trail limits, speed limits, and no e-Bikes allowed. Since all these policies have been implemented within the last year, there have been no outcome assessments to determine how effective they are.

During our webcam analysis, we identified and compared the ages of bikers and e-Bikers to determine what age of people use e-Bikes the most. We found that there was a much higher proportion of e-Bikers were identified as elderly compared to traditional bikers. This difference suggests that elderly bikers may make up a significant portion of e-Bike users and should be investigated further in future studies and this demographic should be considered in relation to any policy decisions.

In order to analyze the different safety behaviors between traditional bikers and e-Bikers, our team mainly researched two indicators: helmet use and speed. Typically, those who wear a helmet are more concerned with safety. Therefore, it was important to compare the rates of helmet usage among both traditional bikers and e-Bikers. From our observational data, we observed that e-Bikers and bikers wore helmets at a similar rate. We also observed that both bikers and e-Bikers typically ride under the park speed limit, indicating that bikers and e-Bikers generally ride at a safe speed.

After developing our findings, we created a series of recommendations for policy makers in Acadia National Park. These recommendations will help to regulate the e-

Biking activity and enhance the safety and visitor experience of e-Bike users and other visitors.

1) *We recommend that the park continue to monitor e-Biking activity.*
2) *We recommend that future researchers take advantage of our e-Bike identification guide.*
3) *We recommend that future researchers study a larger sample size of webcam images over a longer period.*
4) *We recommend that future researchers experiment with automated image identification software.*
5) *We recommend that future researchers use slow-motion cameras to detect speed.*

It is important to continue to monitor the biking activity within the park. As more data is collected, findings may change over time. Based on our findings and future findings, the park can determine the best appropriate practices for e-Bikes and update its policy accordingly.

Our e-Bike identification guide allows users to differentiate e-Bikes from traditional bikes. Any users that want to use the e-Bike identification guide to differentiate an e-Bike need to know the difference between an e-Bike and a traditional bicycle first, which is the essence of the guide. There are new e-Bikes on the market each year, so we recommend that researchers update our guide over time to make sure it is accurate with current e-Bike models that are used within the park.

We also recommend that webcams are placed over a diverse area throughout the park to obtain more accurate data. Biking activity and behavior may differ at other carriage road locations. We also recommend that researchers collect more speed data at different inclines at different locations.

Future research teams could automate the process of identifying e-Bikes by utilizing free, open source software. Simple image processing can analyze an image and automatically input webcam data such as date, time, and temperature. It's important to note that future teams would still have to manually identify e-Bikers from traditional bikers, but computer software could significantly increase the efficiency.

We also recommend that future teams purchase slow motion cameras. Since the AKASO webcams often captured blurry images and may have missed bikers, our team would recommend any webcam with a higher frame rate and trigger speed. A higher frame rate means that cameras can take many more pictures in the same amount of time. Trigger speed refers to the time it takes for a trail camera to detect motion and start capturing images.

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1.0 Introduction

The global market for electric bicycles (e-Bikes) has been growing in recent years (Salmeron & Manzano, 2018). People are increasingly using e-Bikes for everyday transportation and recreation. For example, use them for everyday tasks like commuting to work, going to the gym, or even just picking up a coffee. As e-Bikes are becoming more popular, they have been appearing in National Parks with greater frequency (U.S. Department of the Interior, 2019). In August 2019, the U.S. Department of the Interior issued Policy Memorandum 19-01, which addresses e-Bike use within National Parks. The memorandum defines an e-Bike as “a two- or three-wheeled cycle with fully operable pedals and an electric motor of fewer than 750 watts (1 hp) that provides propulsion assistance”.

There are many benefits associated with e-Bike use in National Parks. For example, e-Bikes increase bicycle access to and within parks by enabling riders to travel longer distances with less effort than with a traditional bike. E-Bikes expand the option of biking to more people, including those who want to ride a bike but don’t because of physical fitness, age, or disability. When used as a substitute for gasoline or diesel-powered transportation modes, e-Bikes can reduce carbon emissions and fossil fuel consumption (U.S. Department of the Interior, 2019). Recognizing the benefits of e-Bikes, the memorandum establishes an e-Bike policy within National Parks stating that e-Bikes are allowed wherever traditional bicycles are allowed.

Although the policy intends to allow e-Bikes to be used similarly as traditional bicycles, the National Park Service recognizes that each park has unique

considerations regarding health and safety. Therefore, individual parks have the authority to impose additional regulations regarding e-Bike use as needed.
For example, Acadia National Park (ANP) has decided to allow e-Bikes wherever traditional bikes are permitted within the park (National Park Service, 2019).

Although e-Bikes have many benefits, there are also safety concerns associated with their speed. Although there are three classes of e-Bikes, class one e-Bikes are the only type of e-Bike that is allowed in Acadia National Park. Class one e-Bikes are characterized by their pedal assist feature that is enacted only when the user is pedaling and limited maximum speed of 20 mph (32 km/h). Other classes of e-Bikes, such as class three, can reach or even exceed 28 mph (45 km/h). The average speed of a traditional bicycle is only about 12 mph, which can be difficult to maintain for long distances. E-Bike users can easily reach 20 mph and maintain it because of the assistance from the electric motor. Since e-Bikes are a relatively new phenomenon, there is little data regarding issues such as e-Bike safety within ANP. This has prompted the park to conduct more research on e-Bikes. ANP has enlisted our help in researching and documenting e-Bike use in the park.

2.0 Background

2.1 National Parks

The National Park Service was created in 1916 to preserve the natural and cultural resources of the National Park System. The mission statement of the National Park Service is to: “preserve... unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations**”** (The National Park Service: What We Do, 2020). The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.” The National Park Service employs more than 20,000 workers to accommodate more than 330 million visitors each year. The National Park Service is a bureau of the U.S. Department of the Interior (The National Park Service: What We Do, 2020).

2.2 Acadia National Park

Acadia National Park was created in 1919 and was the first National Park established east of the Mississippi River. Acadia National Park’s peak season is the summer. Visitors can access many popular sites including Cadillac Mountain, Summit Road, and Sand Beach via the scenic Park Loop Road, shown in figure 1 (Explore Parks: Acadia, 2020).

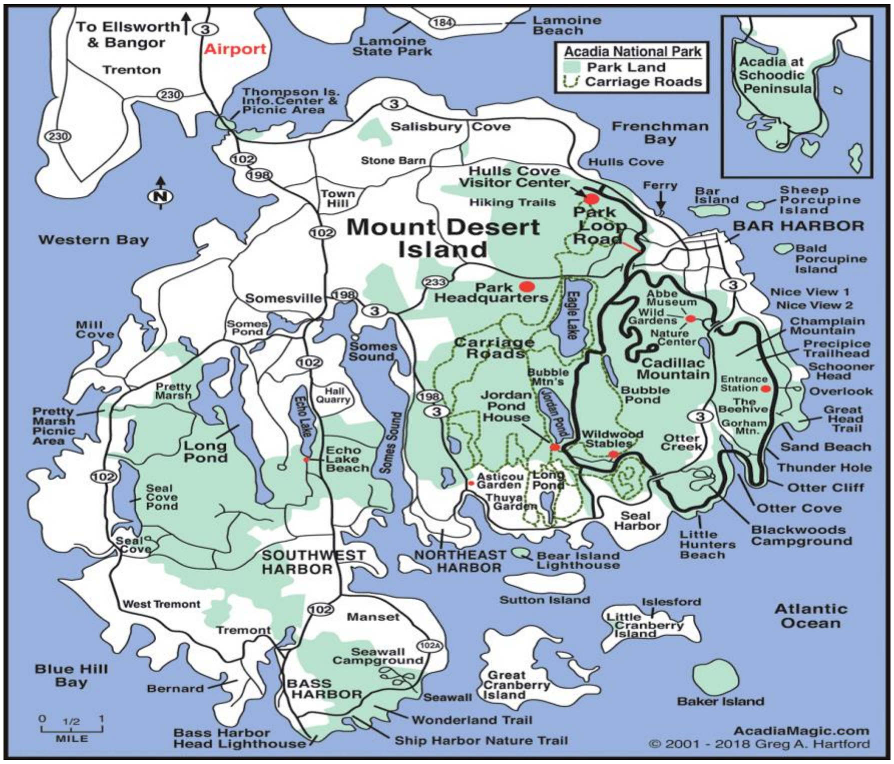

Figure 1: Map of Acadia National Park

Visitors can explore more than 130 miles of hiking trails and bike on 45 miles of carriage roads, as seen in figure 2.

Figure 2:Photograph of Carriage Road in Acadia National Park

Acadia's historic carriage roads were created by John D. Rockefeller Jr. from 1913-1940 for travel by horse-drawn carriages. The carriage roads were originally graded so they were not too steep or sharply curved to accommodate horse-drawn carriages, but this also makes them suitable for biking. The carriage roads were constructed to align with the natural contours of the land and were constructed with native stone and vegetation so that they blend with the landscape. Acadia National Park has formed a partnership with Friends of Acadia to ensure that the carriage roads are maintained close to their original condition (National Park Service, 2018).

2.3 Congestion

As can be seen in figure 3, visitation to Acadia National Park has increased rapidly in recent years. As the number of visitors at Acadia National Park increases each year, the congestion has worsened. Popular roads such as Park Loop Road have become overwhelmed with motor vehicles, bikers, and walkers. This high congestion in the park has led to an increase in safety incidents (involving both cars and bicycles) and a decline in the experience of visitors in the park.

This increase in congestion poses a serious threat to visitor safety (Xiao, 2019). For bicycles, bike congestion on the carriage roads leads to an increased chance of collisions. For motor vehicles, their congestion in the park leads to an increased chance of motor vehicle accidents. As accidents involving bicycles and motor vehicles have become more frequent, emergency vehicles have had difficulty reaching individuals experiencing medical emergencies in the park. As well as posing a serious safety issue, the overcrowded roads greatly diminish visitor experience. Crowded carriage roads and hiking trails make it difficult for visitors to enjoy the nature of the park. It can also be very difficult to explore the entire park without a vehicle, and high traffic rates combined with the difficulty of finding parking can diminish a visitor’s experience.

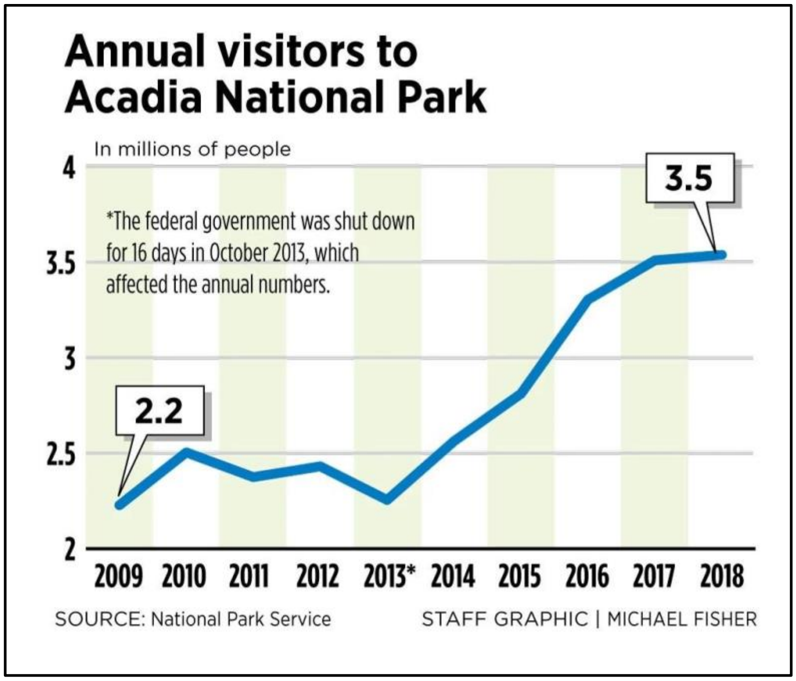

Figure 3: Visitation in Acadia National Park (2009-2018)

2.4 e-Bikes Around the World

E-Bikes are electrified versions of traditional bikes. E-Bikes have a similar design of a regular bicycle to which an electric motor has been attached. The electric motor technology assists riders by generating permanent torque as needed. While e-Bikes were first introduced in the late 19th century, e-Bikes have only recently become popular and have experienced rapid sales growth since the 1990s (EBC, 2018).

As can be seen in figure 4, the global market for e-Bikes is growing rapidly but varies depending on the geographical location, with the Asia-Pacific region currently dominating the market. Worldwide sales were estimated to be 36 million e-Bikes in 2015 with forecasted sales of 100 million units by 2035 (Salmeron & Manzano, 2018).

Figure 4: Electric Bicycle Sales by Region, World Markets 2012-2018

In the United States, the e-Bikes market is relatively small but is growing. As seen in figure 5, the annual number of e-Bike sales in the U.S. increased by more than 100% from 2011 to 2016.

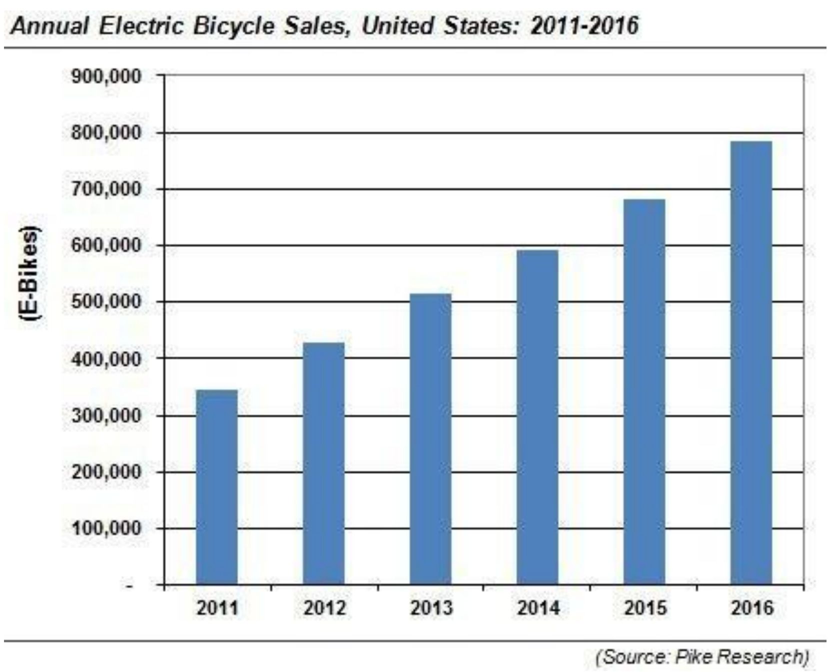

Figure 5: Annual Electric Bicycle Sales, United States 2011-2016

2.4.1 Benefits of e-Bikes

E-Bikes enhance the biking experience. Many e-Bike users are older adults and people who are looking to cycle for recreational purposes. According to an online survey of 553 e-Bike users in North America by Professor John MacArthur from Portland State University, e-Bikes allow users to bike more often and bike for longer distances. The results also suggest that e-Bikes enable riders to carry more cargo and help users lacking physical ability (MacArthur, 2014).

Furthermore, e-Bikes have the potential to improve the efficiency of the transportation system. One of the most significant advantages of e-Bikes over traditional bicycles is the motor on them. (Cherry & Fishman, 2015) The motor not only provides strong power output for users but also increases the distance they can travel. Additionally, since e-Bikes are much faster, the travel time is less than traditional bicycles over the same distance.

Besides transportation and improvement of experiences, using e-Bikes also contributes to the protection of the environment (Astegiano, Fermi, & Martino, 2019). Compared to cars, e-Bikes have nearly zero hot gas (CO, NOx, PM, VOC) emissions. Although e-Bikes consume more energy than traditional bicycles, they do not contribute significant hot gas emissions to the total carbon footprint. Therefore, e-Bikes are both practical and environmentally friendly transportation modes.

The transport sector accounts for nearly one-quarter of global energy-related carbon dioxide emissions, mainly due to cars and trucks traveling on roads (Astegiano, Fermi, & Martino, 2019). The increase in the use of active modes of transport affects the amount of greenhouse gas and air pollutant emissions (CO, NOx, PM, VOC). The

ASTRA environment module (the strongest model when it comes to the integrated assessment of impacts of transport strategies in Europe), found that e-Bikes are generally very energy-efficient and environmentally friendly (Astegiano, Fermi, & Martino, 2019). Power sector emission factors are an indication of the intensity of carbon emissions. A higher emission factor indicates more carbon emissions. Under the same distance traveled, e-Bikes consume about one-tenth the energy consumption of a small electric car, and around 40 percent less carbon dioxide than a standard car. Even where the power sector has among the highest emission factors (e.g. China and Australia), emissions of carbon dioxide and other conventional pollution from e-Bikes are relatively low. Other countries, where e-Bikes are gaining popularity (e.g. the Netherlands and Germany), have power sector emissions factors that are approximately half those of China and Australia, further reducing emissions rates of e-Bikes (Fishman, 2016).

Besides reducing carbon emissions, e-Bikes also alleviate traffic congestion. One advantage of e-Bikes compared to cars is their flexibility. E-Bikes allow their riders to negotiate traffic conditions and regulations as permitted by laws. E-Bikes can move faster than traditional bicycles, providing the ability to travel around 20 to 25 miles an hour. The pedal-assist or throttle of the e-Bike also makes obeying stop signs or going uphill less onerous. Some e-Bike users said the ability to use the throttle to accelerate quickly at a stop sign reduced the time it took for them to traverse the downtown area (where stop signs are frequent), made them less worried about waiting cars becoming impatient, and greatly decreased the physical effort needed to start from a complete stop. All these factors were seen as enabling the e-Bike to interact, on the road, more like an automobile. It was repeatedly mentioned that these advantages were magnified by the fact that the current traffic rules and road facilities are overwhelmingly designed to accommodate cars. In this way, and due to the implications of greater speed, e-Bikes are well suited to the American transportation challenges presented by auto-centric design and relatively low-density land use. The e-Bike can function, in some ways, more like a car, without losing some of the environmental and economic benefits of a bicycle.

2.4.2 Concerns about e-Bike Safety

Even though e-Bikes have many benefits, there are concerns regarding their safety. According to a survey of 663 e-Bike users in Denmark, 29% of users had been involved in an e-Bike accident that they believed wouldn't have happened on a traditional bike. The most frequent explanation offered for these situations was that other road users had underestimated the speed of the e-Bike, followed by rider problems regulating e-Bike speed. (Haustein, 2016).

Another study compared e-Bikes to traditional bicycles and discussed e-Bike safety. An online survey was conducted of 553 existing e-Bike users in North America regarding their purchase and use decisions. The researchers found that 60% of e-Bike owners felt safer while riding an e-Bike, compared with a traditional bike, and 42% of e-Bike owners said the e-Bikes had assisted in avoiding crashes. The reasons are given to explain this apparent effect ranged from increased acceleration to clear an intersection, keeping up with traffic, and improved balance at higher speeds (MacArthur, 2014).

An investigation was done on 23 crashes (involving both e-Bikes and traditional bikes) that were reported to the emergency departments (EDs) in Europe (MacArthur, 2014). For both traditional bicycles and e-Bikes, one-quarter of the reported crashes result in head injuries, with upper extremities being the second-highest injured region. Using data from EDs, the author analyzed another 294 e-Bike and 1,699 bicycle crashes. He concluded that after controlling for age, gender, and the amount of cycling, e-Bike use is associated with a fairly small increase in the risk of ED treatment due to a crash.

2.5 e-Bikes in Acadia

2.5.1 Classes of e-Bikes

Class 1 e-Bikes are pedal-assist only, meaning the motors are passive until the user begins to pedal. This class of e-Bike also has a maximum speed of 20mph. Class 2 e-Bikes have the same maximum speed, but are throttle-assisted instead - the user can still pedal to travel faster than the maximum speed, but pedaling is not required to travel up to 20mph. Class 3 e-Bikes are similar to class 1 e-Bikes in the sense that they are pedal-assist, however, they have a higher maximum speed of 28 mph (National Park Service, 2019).

Since the maximum speed of class 3 e-Bikes is higher than class 1, we can assume that the distance required for class 3 e-Bikers to brake is longer than the distance required for class 1 e-Bikers. The longer the distance to brake, the more difficult it is to stop or to avoid a collision. Therefore, the high speeds and autonomy of these e-bikes make them more dangerous than class 1 e-Bikes.

Since there is little research done on the safety effects of e-Bikes, the park has taken a more cautionary approach in allowing them. The high speeds and autonomy of class 2 e-Bikes and class 3 e-Bikes make them too risky to implement right away.

Instead, the park has chosen to only allow class 1 e-Bikes due to the lower maximum speed and pedal-assist. Class 2 and 3 e-Bikes are not allowed in Acadia National Park. As seen in figure 6, Acadia National Park has posted speed limit signs along the carriage roads so that visitors are aware of the e-Bike policy.

Figure 6: Speed Limit Sign along Carriage Road in Acadia National Park

Class of e-Bike	**Pedaling required to move?**	**Max Speed**	**Allowed in Acadia National Park?**
Class 1	Yes	20 mph	Yes
Class 2	No	20 mph	No
Class 3	Yes	28 mph	No

Table 1: Classes of e-Bikes

2.5.2 Current e-Bike Etiquette

Class 1 e-Bikes are currently permitted everywhere traditional bicycles are permitted in the park. This means that e-Bikes and normal bicycles are not allowed on private property or any of the hiking trails. However, e-Bikes and normal bicycles are allowed on park roads that have motor vehicles. Roads that allow e-Bikes and motorized vehicles include the Park Loop Road and Summit Road. Also, traditional bikes and e-Bikes are allowed on the public carriage roads, where motorized vehicles are prohibited (National Parks Conservation Association, 2019).

3.0 Methodology

The goal of this project was to study the prevalence and behaviors of e-Bike users in Acadia National Park to determine effective policies for e-Bike use within the park. The first objective was to compare Acadia National Park's existing e-Bike policy with e-Bike policies of other locations. The second objective was to observe and analyze the behaviors and practices of e-Bikers and bikers in the through webcam images. The third objective was to explore the feasibility of using webcams to monitor biking activity on the carriage roads.

3.1 Compare Acadia National Park's Existing e-Bike Policy with e-Bike Policies of Other Locations

We explored e-Bike policies in different national parks in order to understand and compare the different ways national parks are implementing e-Bike policies. Many studies follow a similar approach when conducting research related to policy making. They study, compare, and analyze the policies made by different organizations in order to determine what policies are most efficient. (Verma, Patel, Nair, & Brent, 2018).

Our first objective was to compare Acadia National Park's existing e-Bike policy with e-Bike policies of other locations. To meet this objective, we studied strategies that other national parks have employed to regulate e-Bike use. After researching e-Bike policies implemented by other parks, we identified which parks adopted the National Park Service's e-Bike policy, which permits all three class of e-Bike, and which parks implemented additional restrictions. We compared the more restrictive policies based on what classes of e-Bikes are permitted, where e-Bikes are permitted, and speed limits.

By studying the related strategies that have been implemented in these other places, we were able to compare the different rules and regulations to develop a better understanding of potential policy options for e-Bikes in Acadia National Park.

3.2 Observe and Analyze the Current Behaviors and Practices of e-Bikers and Bikers in the Park through Webcam Images

Our second objective was to observe and analyze the behaviors and practices of e-Bikers and bikers in the park. To meet this objective, we collected demographic and behavioral data on e-Bikers and traditional bikers by installing the Spypoint FORCE-20 (figure 7) motion detecting webcam in several different locations in the park. Figure 8 is an example of an image of an e-Bike taken with the Spypoint FORCE-20 webcam.

Figure 7: Spypoint Force-20 Webcam

Figure 8: An e-Bike Image taken with a Spypoint Force-20 webcam

Collecting this data helped identify the biking activities and trends in Acadia National Park to come up with insights into patterns of behavior. Although we investigated many variables, we focused on analyzing the ratio of e-Bikes to bikes, age, and safety.

Our team collected data over several weeks in order to obtain a large sample size of traditional bikers and e-Bikers. For example, we recorded general data such as location, day of the week, time of day, temperature, and bike type. We also recorded demographic data such as age, gender, and the number of people in each image. We collected behavioral data such as speed, whether the biker was wearing a helmet, and the type of clothing worn. The choice of collecting such data was to have as many details as possible of who is using an e-Bike, where, and when. The data could also helpful to define regular bikers as well. All the images were analyzed manually by a team member, and the information was added to a shared spreadsheet. Then, other team members went over the images again to confirm the collected information and conduct quality control.

For age recognition, we developed a manual processing methodology that each team member followed to identify the age of the biker in each image. Firstly, we divided and categorize age into four age groups: kid, young, adult, and elderly. We recognized people under 18 as kids, between 19 and 30 as young, between 31 and 55 as adults, and above 55 as elderly. Then, the team member would examine the images and manually identify key aging features such as anthropometry and wrinkles to classify the biker into one of the age groups we created (Dehshibi & Bastanfard, 2010).

As seen in figure 9, the first webcam was placed near Jordan Pond on June 19th, because we had determined it was an active spot despite the COVID-19 pandemic. Unfortunately, most of the activity captured by the webcams was hiking and horseback riding.

Figure 9: Placement of webcam at Jordan Pond

On June 26th, we moved the webcam to a three-way intersection along the Carriage Roads near Upper Hadlock Pond, where a noticeable increase in biking activity was observed (figure 10). Two additional motion detector webcams were installed along a section on the Carriage Roads to monitor the speed of bikers.

Figure 10: Placement of webcam at Upper Hadlock Pond

After a couple of days, the webcams were moved to the Ocean Drive/Otter Cliff intersection (figure 11) on the Park Loop Road for about a week. This spot had a little incline on it and was shared with motorized vehicles.

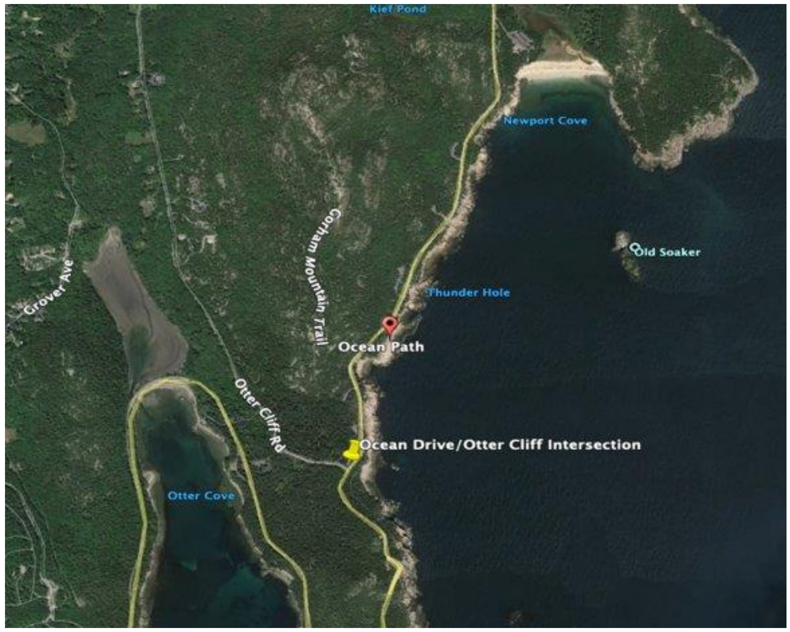

Figure 11: Placement of webcam at Ocean Drive/Otter Cliff

Then, the webcams were moved back to the Carriages Roads near Eagle Lake (figure 12). Eagle Lake is known to be a particularly active area. We had originally expected the Carriage Roads near Eagle Lake to be closed due to construction, they remained open during the COVID-19 pandemic.

Figure 12: Placement of webcam at Eagle Lake

We processed data by manually going through each webcam image and inputting key information into Excel. Our Excel spreadsheet was connected directly as a database to Tableau, a software used to analyze and visualize the data. The essence of using Tableau was to analyze and develop an interactive visualized dashboard for our data that will make it easier for us and the decision-makers to understand the information within our collected data.

The webcams used motion-detecting technology to capture an image each time a biker or e-Biker passed in real-time. Also, by setting up two AKASO TCO4 webcams, shown in figure 13, along the trail at a known distance apart, we calculated how fast each bike was traveling.

Figure 13: AKASO TCO4 Webcam

We used AKASO TCO4 webcams because they could record the time to the nearest second, making our calculations more accurate than if we were to use the Spypoint FORCE-20 webcams, which only record the time to the nearest minute.

As shown in figure 14, we placed the cameras 125 feet apart, and then used the following formula to calculate the speed in miles per hour(mph): (125 / time between cameras in seconds) x 3600 / 5280 = speed(mph).

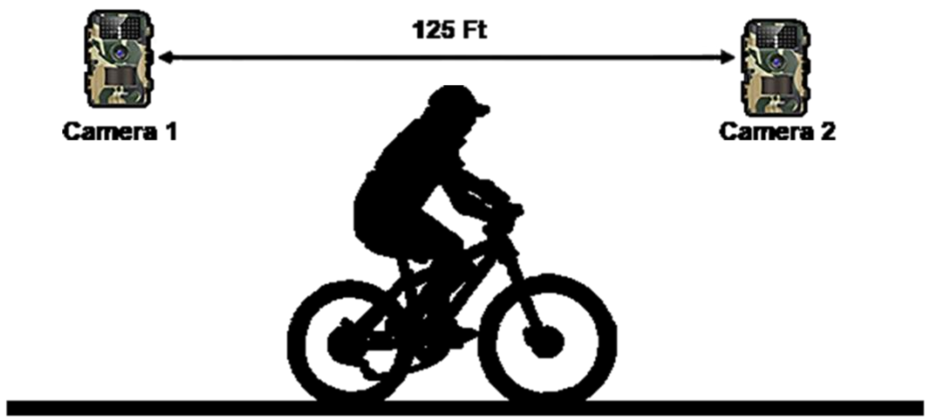

Figure 14: Speed Calculations

We made several charts and graphs that show demographics and behavioral patterns about the e-Bikers and traditional bikers at Acadia National Park. We started it off by making comparison charts of which demographics used e-Bike versus regular bikes. We took note of important information such as gender, age, safety (such as if bikers wear helmet), type of clothing worn. This was helpful to get an insight into what kind of people are using an e-Bike, how many e-Bikes are being used in the park, and who is taking the protective measures by wearing a helmet. When we checked whether bikers wore a helmet or not, our team decided to include bikers who were carrying helmet but not wearing them into the “no helmet” category.

3.3 Explore the Feasibility of Using Webcams to Monitor Biking Activity on the Carriage Roads

While using the cameras to observe and identify e-Bikers, we also assessed the feasibility of using webcams as a viable technique to monitor biking within the park. Examples of the difficulties that we have faced are the time needed to collect the data manually from the webcam images, identifying e-Bikes from for each image, detecting the speed of bikes form the images, and scaling up the biking monitoring to more locations inside Acadia National Park.

For our observations, we used motion-detecting webcams in order to monitor biking activity remotely. In order to clearly observe each location, we experimented with different methods of webcam placement.

We first experimented with the webcam's proximity to the trail. At Jordan Pond, the webcams were placed close to the trail. Then at Upper Hadlock Pond, they were placed slightly further from the trail to capture a wider view of the intersection. Finally, webcams were placed at Eagle Lake at the same distance from the trail as they were at Upper Hadlock Pond. Eagle lake is known to be a busier area, so we were able to observe many bikes.

Towards the end of our research, we were able to automate part our data collection by using image processing, optical character recognition, and excel to single out certain variables like time, date, and temperature. First, the images were uploaded into a folder where they were cropped to only show the text at the bottom. We did this using an image processing software called BatchPIE. Next, we ran a custom optical character recognition pipeline to identify the text in the images and upload them into excel. Finally, we used the java-based software Tesseract to extract relevant info into excel. A detailed explanation of our software can be found in Appendix F. Our team experimented with this software and proved it to be useful, but still manually inputted all of our webcam data.

Initially, when analyzing images from the webcams, we realized that it is difficult to differentiate e-Bikes from traditional bikes. Since traditional bicycles and e-Bikes often look very similar, therefore, we created an e-Bike identification guide to make it easier to identify e-Bikes (Appendix A). Initially, our team tried to organize the guide by listing e-Bike brands, but we realized that it is easier to identify e-Bikes based on certain characteristics. We focused on the battery and motor, which were unique to e-Bikes. As we collected our data, we observed some particularly confusing e-Bikes. We included images of these e-Bikes in our identification guide as well. We also encountered many of the same e-Bikes, so we included their images as well to increase our accuracy and efficiency in identifying e-Bikes.

4.0 Findings

Finding 1: Of 3,310 Bikes we Observed in Acadia National Park, Only 3% Were e-Bikes

Since this is the first year e-Bikes have been allowed on the carriage roads in Acadia National Park, there has been no accurate estimate of just how many e-Bikers there are. Our team, in order to assess the number of e-Bikers in the park, manually counted the number of traditional bikers and the number of e-Bikers captured on the webcams.

Towards the beginning of our data collection, when the first cameras were placed in mid-June, we observed few e-Bikers. However, in July, we began to see more e-Bikers on the webcams. In total, after observing 3,310 bikes, 115 were identified as electric. This corresponds to about 3% of bikers observed on the webcams utilizing electric bikes.

When making recommendations for policies, it is important to expect this data to change. Since this is the first year that e-Bikes have been allowed on the carriage roads, our team expects the total number of e-Bikes in the park to change in future years.

Finding 2: Other National Parks Have Imposed e-Bike Restrictions but Outcome Assessments Still Need to be Done.

We compared the e-Bike regulations of 45 other National Parks with Acadia's e-Bike regulations. The 45 National Park Policies are included in Appendix B. Fifty-two percent of these National Parks implemented the National Park Service's e-Bike Policy, which states that e-Bikes are permitted wherever traditional bikes are permitted. Forty-eight percent of these National Parks imposed additional restrictions on e-Bike use.

As illustrated in figure 15, these additional restrictions include class restrictions, trail limits, speed limits, and no e-Bikes allowed. Eleven National Parks have implemented multiple restrictions, so they are represented multiple times in figure 15. For example, Acadia National Park has imposed class restrictions and speed limits, so it is represented by the yellow and blue slices in figure 15.

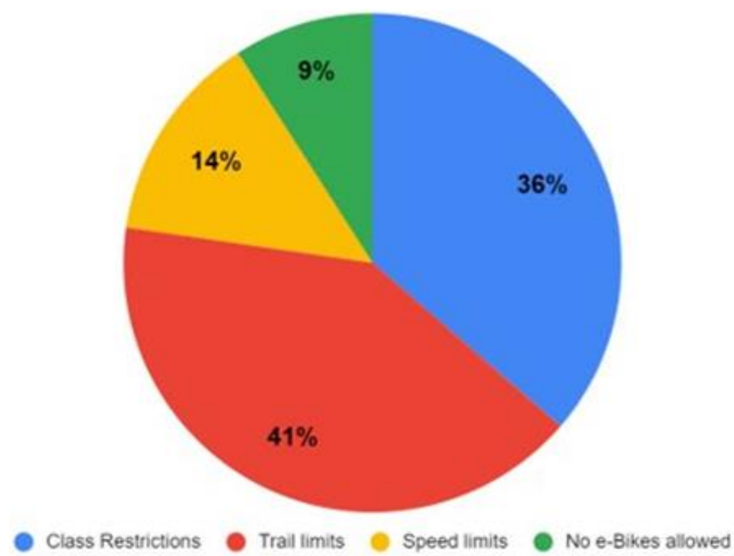

Figure 15: Types of E-Bike Restrictions

Since these policies were only implemented within the last year, there have been no outcome assessments describing the impact on safety and visitor experience. By studying the related strategies that have been implemented in these other places, we were able to compare the different rules and regulations to develop a better understanding of potential policy options for e-Bikes in Acadia National Park.

Finding 3: There is a Higher Percentage of Elderly e-Bikers in Acadia National Park Than Elderly Traditional Bikers

At the beginning of this project, our team was curious about what age of people use e-Bike the most. Therefore, when our team members analyzed those images from webcams, we identified and compared to the ages of bikers, shown in figure 16. Our team assigned one of four labels to individuals captured on the webcams; kid, young, adult, or elderly. We estimated kids to be under the age of 18, young to be within the age range of 18 to 30, adults to be from 31 to 55, and elderly individuals to be over 55 years old. We found that most users, both bike and e-Bike, were predominantly in the adult category. However, looking at the age components for bikers and e-Bikers, we found that there was a much higher proportion of e-Bikers were identified as elderly.

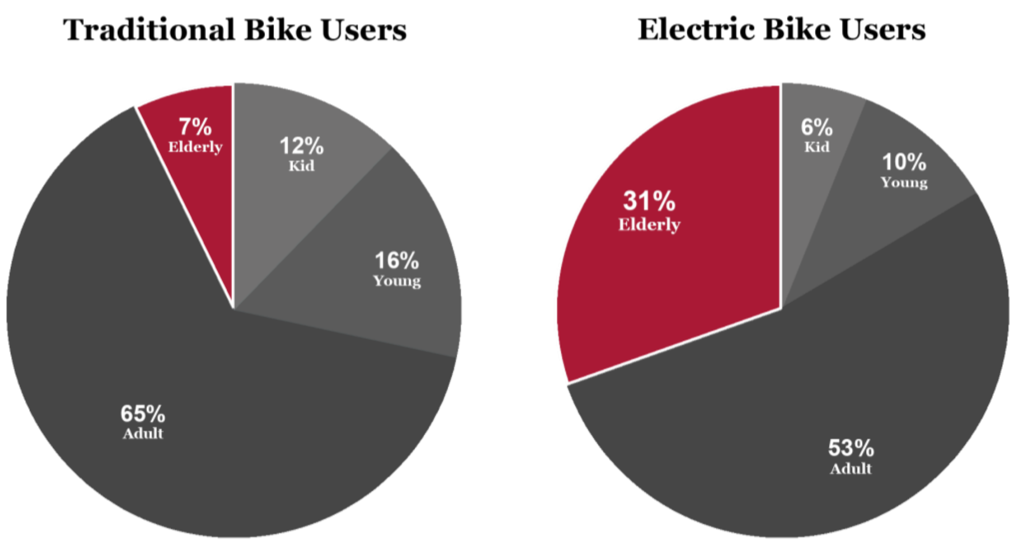

Figure 16:Helmet Use among Traditional Bike Users vs. E-Bike Users

From the elderly group of traditional bikers, you could see that only 7% were elderly. However, that percentage increased to 31% for e-Bikers. This difference suggests that elderly bikers may make up a significant portion of e-Bike users and should be investigated further in future studies and this demographic should be considered in relation to any policy decisions.

Finding 4: The Safety Behaviors of e-Bikers and Traditional Bikers are Similar

In order to analyze the different safety behaviors between traditional bikers and e-Bikers, our team mainly researched two indicators: helmet use and speed.

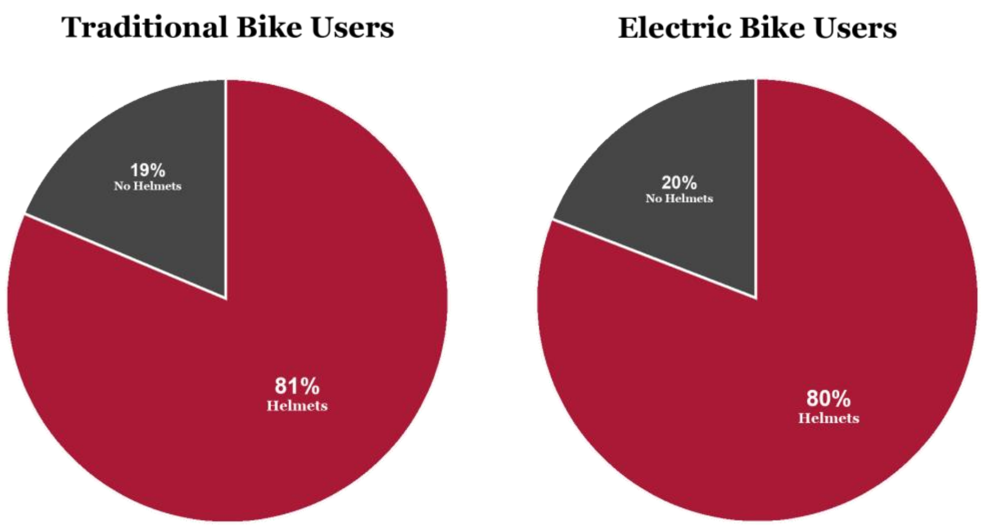

Figure 17: Helmet Use among Traditional Bike Users vs. E-Bike Users

As seen in figure 17, there is no distinguishable difference in the rate at which both these groups wear helmets. Helmet use may not be the component that affected e-Bikers' safety compared to traditional bikers.

Beside helmet use, our team also measured the speed by putting two webcams 125 feet apart at Upper Hadlock Pond. We observed 152 bikers and 3 e-Bikers in total.

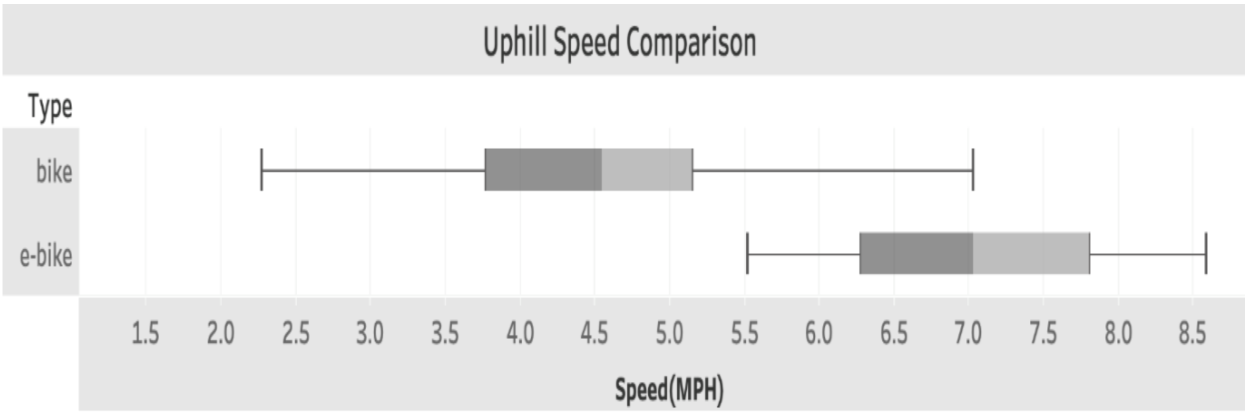

Figure 18: Speed Comparison of e-Bikes and Bikes

Figure 18 shows that the average speed for uphill bikers was 4.5 mph, and it was about 7 mph for e-Bikers. Moreover, the range indicates that even the slowest e-Biker was faster than the average speed of bikers. Both e-Bikers and bikers rode under the speed limit of 20 mph. Our team observed some bikers whose speeds were between 12-16 mph, but there were only 4 of them and they were also under the speed limit of 20 mph. The maximum speed we observed was 16 mph. Our team observed some empty images, where no bikes were captured. These empty images could be bikers or e-Bikers who are riding too fast for the cameras to capture. These bikers may be riding faster than the fastest speed we observed, 16 mph, indicating they may be speeding. However, there is no way to know this for sure.

To make sure the AKASO webcams weren't missing traditional or electric bikers exceeding the speed limit, our team estimated the minimum speed a biker would have to achieve to avoid being captured on the webcam. To calculate this number, we first needed to know what length of carriage road was visible from the camera's 120 degree (Ross, 2020). We were able to estimate the length of the road by analyzing a webcam image's pixel ratios. Figure 19 shows the ratios of a traditional biker to negative space in one of the images.

Figure 19: AKASO Field of View Estimation

From these pixel ratios, we used the following equation to calculate the field of view (FOV) width.

$$\frac{total\ image\ width(pixels)}{FOV\ \ width\ estimate(inches)} = \frac{bike\ width(pixels)}{average\ bike\ length(inches)}$$

After substituting for appropriate values, the equation reads:

$$\frac{(275+170+195)\ pixels}{FOV\ \ width\ estimate(inches)} = \frac{275\ pixels}{68\ inches}$$

We solved this and calculated the field of view width to be 158.25 inches, or 13.19 feet. Once we had an estimate of the length of the carriage road segment, we used the 0.4 second trigger speed of the AKASO camera to calculate the minimum speed a biker would need to achieve in order to pass by the camera undetected. We then converted the 32.9 ft/s to miles per hour, or 23 miles per hour.

Although our calculated 23 mph minimum speed isn't an exact value, it demonstrated that very few bikers came anywhere close to reaching a fast enough speed to pass the webcam undetected. From this, we concluded that bikers and e-Bikers maintain safe speeds. However, that conclusion is not representative of the entire park, since it came from limited data and only represents an uphill incline.

After we have collected the data about helmet use and speed, our team tried to identify a relationship between them (Appendix C). The graph does not indicate a clear relationship between helmet use and speed, as distributions had similar average speed and range. Even though the speed range of bikers who wear helmets was smaller than the speed range of bikers who did not wear helmet (from 4-6 mph and 4-7 mph respectively), the difference is too small to make a conclusion.

5.0 Recommendations

Under the unique circumstances of COVID-19, the observational part of our project was based solely on images delivered from the motion detecting webcams. From analyzing and distinguishing the e-Bikes in the images, our team has gained a lot of valuable knowledge. Based on our results, we developed some recommendations for future research into e-Bike use in Acadia National Park. These recommendations will help to inform regulations and enhance the safety and visitor experience of e-Bike users and other visitors.

5.1 We recommend that the park continue to monitor e-Biking activity

We have collected observational data on biking practices in Acadia National Park over a three-week period. During this time, we observed and analyzed 3,310 bikes. Out of this number we only identified 115 e-Bikes. That is equal to approximately 3% of the total observed bikes. It is important to keep monitoring the biking activity within the park over time, as the policy is still new and not all visitors are aware of it yet. Also, during the COVID-19 pandemic, people could be behaving in a different way than normal. This could have influenced our results. Therefore, continuing to monitor the biking activity is important for capturing an accurate picture of bike and e-Bike use in the park. Based on our findings and future studies, the park can determine the best appropriate practices for e-Bikes and change its policy accordingly.

5.2 We recommend that future researchers take advantage of our e-Bike identification guide

We tested and improved the identification guide throughout our project. The e-Bike identification guide introduces the basic differences between a traditional bike and an e-Bike, such as the battery and the motor at the beginning. We further organized e-Bikes into different categories such as external or internal batteries. When we observed more and more e-Bikes, we found several particularly confusing e-Bike types. So, we provided visual examples of e-Bikes we observed in our webcam images to help observers better understand how to differentiate an e-Bike.

There are new e-Bikes on the market each year, so we recommend that researchers update our guide over time to make sure it is accurate with current e-Bike models that are used within the park. We also recommend future researchers update our guide with additional unique e-Bike features as new e-Bikes are developed.

5.3 We recommend that future researchers study a larger sample size of webcam images over a longer period.

Our primary recommendation is to study a much larger sample size of webcam images over a longer period. We recommend placing webcams at populated areas such as Eagle Lake, where our team observed the most bikers and e-Bikers. Due to our limited time and budget, we were unable to obtain images from every carriage road. Therefore, we recommend that webcams are placed over a diverse area throughout the park to obtain more accurate data. Biking activity and behavior may differ at other carriage road locations. We also recommend that researchers collect more speed data at different inclines at different locations.

5.4 We recommend that future researchers experiment with automated image identification software

We also have some technical suggestions for future researchers studying e-Bike use. Although our webcam analysis allowed us to draw useful conclusions, there are types of software that make webcam analysis more efficient. There is an image recognition mobile application called Google Goggles. Its purpose is to translate images to words or help recognize common entities, such as walkers or bikers. Future teams can take pictures in National Park and use this application to identify bikers. After our group completed some tests with this software, we found that there were some major issues. First, the software had a difficult time differentiating an e-Bike from a traditional bike. Second, it's prone to misidentifying entities. We recommend that future groups explore different forms of computer vision to automatically identify e-Bikes.

After our team designed our own computer vision software, we recommend that future groups use something similar. Creating this program was just a proof of concept that the park, or future research teams, could automate the process of identifying e-Bikes. Future teams would still have to manually identify e-Bikers from traditional bikers, but this software could double a group’s efficiency.

5.5 We recommend that future researchers use slow-motion cameras to detect speed

Our final suggestion relates to speed calculations. When attempting to calculate speed, some bikers (both e-Bike and traditional) ride too fast to capture. Sometimes you only capture an empty image. If future teams want to get more accurate data, we suggest they purchase a slow-motion camera. The slow-motion webcam we describe is not necessarily the traditional “slow-motion” webcam which will take thousands of images in a second and prolongs that second to make the motion they detect seems like slow-motion. A “slow-motion webcam” could simply be a better trail camera or motion-detect webcam that have higher frame rate and trigger speed. The higher frame rate allow users to choose the best position of the object they observe from images the webcams took in that duration, and the higher trigger rate will make sure the webcam will react much faster than usual camera, which ensures the webcam will catch something rather than an empty images.

6.0 Conclusion

This is the first year that Acadia National Park has allowed class 1 e-Bikes on the Carriage Roads where traditional bikes are allowed, consistent with the National Park Service's Policy Memorandum 19-01 on Electric Bicycles. Acadia National Park lacks data needed to implement an effective e-Bike policy. Our goal was to study the impact of e-Bikes on visitors' safety and experience to provide insights to the policy makers in order to improve their current e-Bike policies.

We monitored biking activity at several intersections using images from motion detecting webcams. We have found that *of the bikes we observed, only 3% were e-bikes, there is a higher percentage of elderly e-Bikers in Acadia National Park than elderly traditional bikers, and the safety behaviors of e-Bikers and traditional bikers are similar.* This project establishes a baseline for future research into e-Bike use in Acadia National Park. By following our recommendations and continuing to research e-Bike usage in the park, Acadia National Park can monitor and adjust their e-Bike policy to preserve the safety and experience of its visitors.

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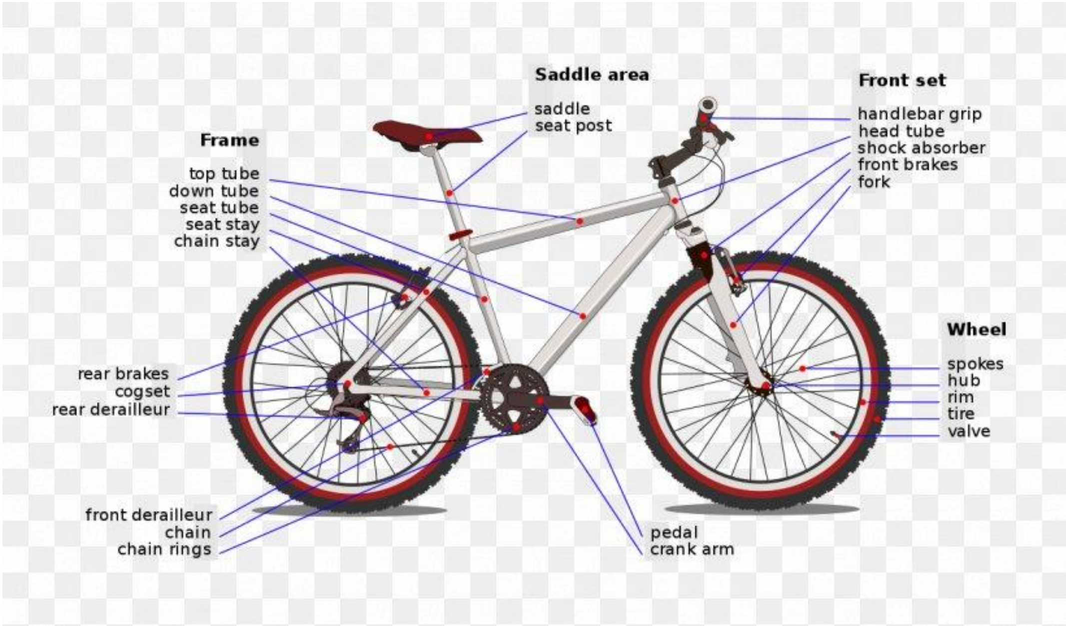
Appendix A: E-Bike Identification Guide

Base shape and components of a traditional bicycle



e-Bikes look similar to the traditional bicycle, with additional components such as a battery and motor.

Battery Placement	**Description**	**Example**
External Battery	The battery in this kind of e-bike comes added externally on the frame. usually, it is added on the middle frame where people used to make it a place to hold their water bottles	
Integrated Battery	The battery in this kind of e-bikes comes integrated with the frame. usually, it is integrated into the lower middle frame resulting in a bigger, heavier lower frame.	

Motor Type	Description	Example
Hub Motor	This kind of motor is attached to either the front or rear wheel to provide power to the wheel itself. e-bikes with this kind of motor usually are gearless making it better for flat riding.	
Mid-mounted /Crank-drive motor	This kind of motor is mounted at or near the chainring. This motor type provides power to the chain itself that is able to transfer the electric power to mechanical and move the bike.	

If you are still not sure whether you are looking at a bike or e-Bike, you can also identify e-Bikes based off of the company or brand. Here are some e-Bike companies or stores who are selling or renting e-Bikes near Acadia National Park.

1. Pedego Electric Bikes Acadia (www.pedegoelectricbikes.com)

It is difficult to identify the e-Bike above because you cannot really see a motor outside or an obvious battery, which is actually the back seat. An easy to identify this type of e-Bike from a traditional bicycle is to look at the brand: PEOEGO. After you have found the brand, you can try to search on “google picture search” to find out if it is really an e-Bike. From the data we have collected, if the similarity is more than 85%, you can assume that it is an e-Bike.

The e-Bike above is also a PEDEGO e-Bike whose appearance looks like a bicycle. For this kind of e-Bike, you even cannot see the battery since the battery is hiding in the bumper, which has the brand name on it. The motor is on the rear wheel, so you may see it from one side, but not the other one. If you are lucky, you can see the motor and identify it easily; however, when you look at the bicycle from an angle you need to use a different technique to differentiate this type of e-Bike from a bicycle. The most accurate method is to look at the brand, then go to the store to check, but if you want to save some time, you can just check the down frame, which has the brand name on. More than 90% of the traditional bicycle images we have collected in Acadia National Park show us that they have a thin down frame, especially for the competition bicycle, because they need to be as light as possible. So, if you saw a big, huge down frame, you can assume that it is an e-Bike since the battery should be inside.

2. Lectric eBikes (https://lectricebikes.com)

The picture above depicts one of the e-Bikes sold by the Lectric eBikes. This type of e-Bike has a totally built-in battery. So you may not want to differentiate them based on whether they have a battery. However, you will quickly realize what's special - the uncommon big wheel.

3. Rad Power Bikes (www.radpowerbikes.com) (https://acadiaebikerentals.com/)

The first website above is a famous company that produces e-bike, Rad Power Bikes, and the second link leads you to a website where people can rent e-bike in Acadia National Park. Most of the e-Bikes that are available to rent at stores in Acadia are the same type of bike, and the picture shows some typical type.


RADROVER
RAD POWER BIKES
KENDA


RAD POWER BIKES
KENDA

The three e-Bike pictures above show all the possible battery positions that could be on a rental e-Bike that you may find in Acadia National Park. Moreover, these e-Bikes all have a common light fixated at the front of the e-Bike. This light is another feature that can help identify an e-Bike.

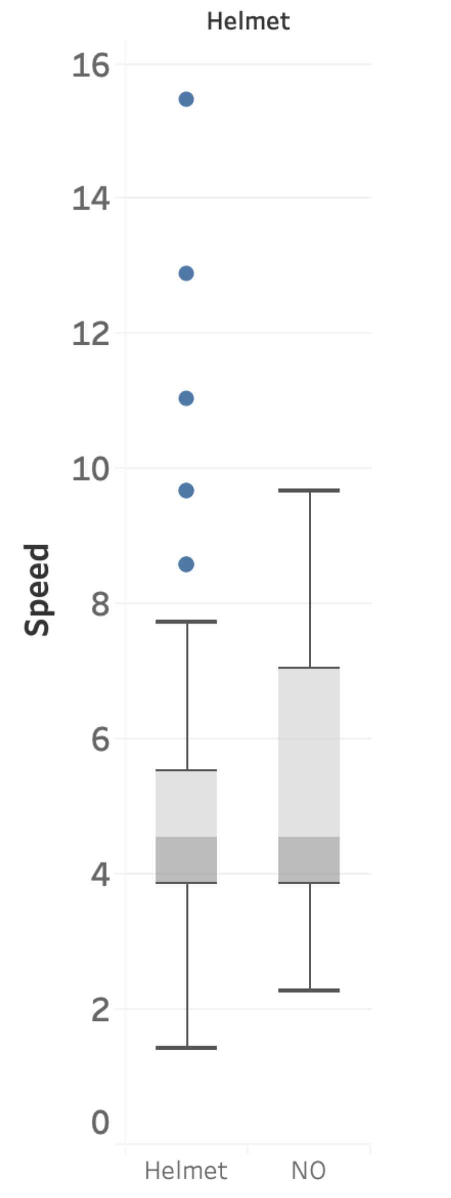
This e-Bike was the most commonly observed e-Bike from our webcam images.

Appendix B: E-Bike Policies of 45 National Parks

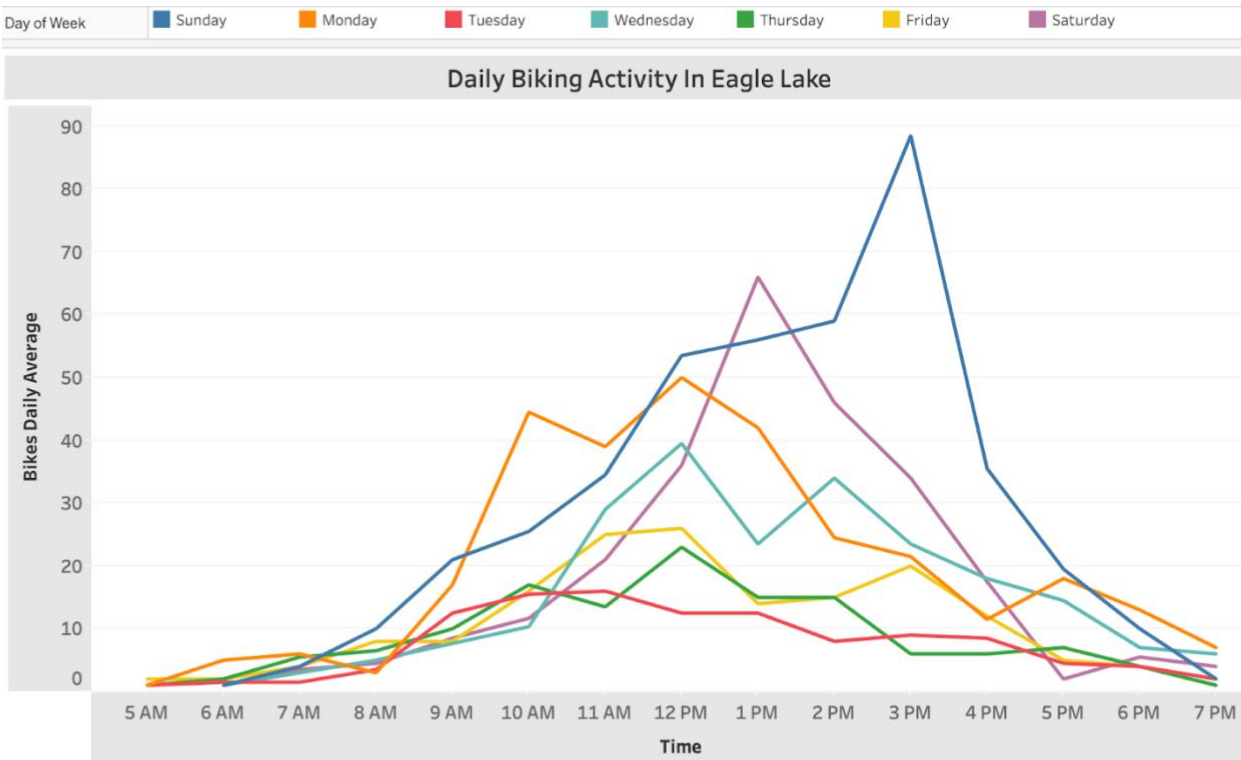
National Park	No Restrictions	Class Restrictions	Trail limits	Speed limits	No e-Bikes allowed
Denali National Park and Reserve	x				
Bering Land Bridge National Preserve	x				
Glen Canyon National Recreation Area	x				
Golden Gate National Recreation Area	x				
Lassen Volcanic National Park	x				
Point Reyes National Seashore					x
John Muir National Historic Site	x		x		
Dinosaur National Monument	x				
National Mall and Memorial Parks	x				
Everglades National Park		x		x	
Cape Cod National Seashore	x				
Chesapeake and Ohio Canal National Historical Park			x	x	
Acadia National Park		x		x	
Glacier National Park	x				
Lake Mead National Recreation Area	x				
Tule Springs Fossil Beds National Monument	x				
Cuyahoga Valley National Park		x	x		
Crater Lake National Park	x				
Gettysburg National Military Park	x				
Eisenhower National Historic Site	x				
Great Smoky Mountains National Park		x			
Arches National Park	x				
Canyonlands National Park	x		x		

Hovenweep National Monument	x		x		
Natural Bridges National Monument	x				
Bryce Canyon National Park					x
Zion National Park		x			
Mount Rainier National Park	x				
Olympic National Park			x		
New River Gorge National River		x	x		
Gauley River National Recreation Area		x	x		
Bluestone National Scenic River		x	x		
Harpers Ferry National Historical Park	x				
Yellowstone National Park	x				
Grand Teton National Park	x				
National Elk Refuge	x				

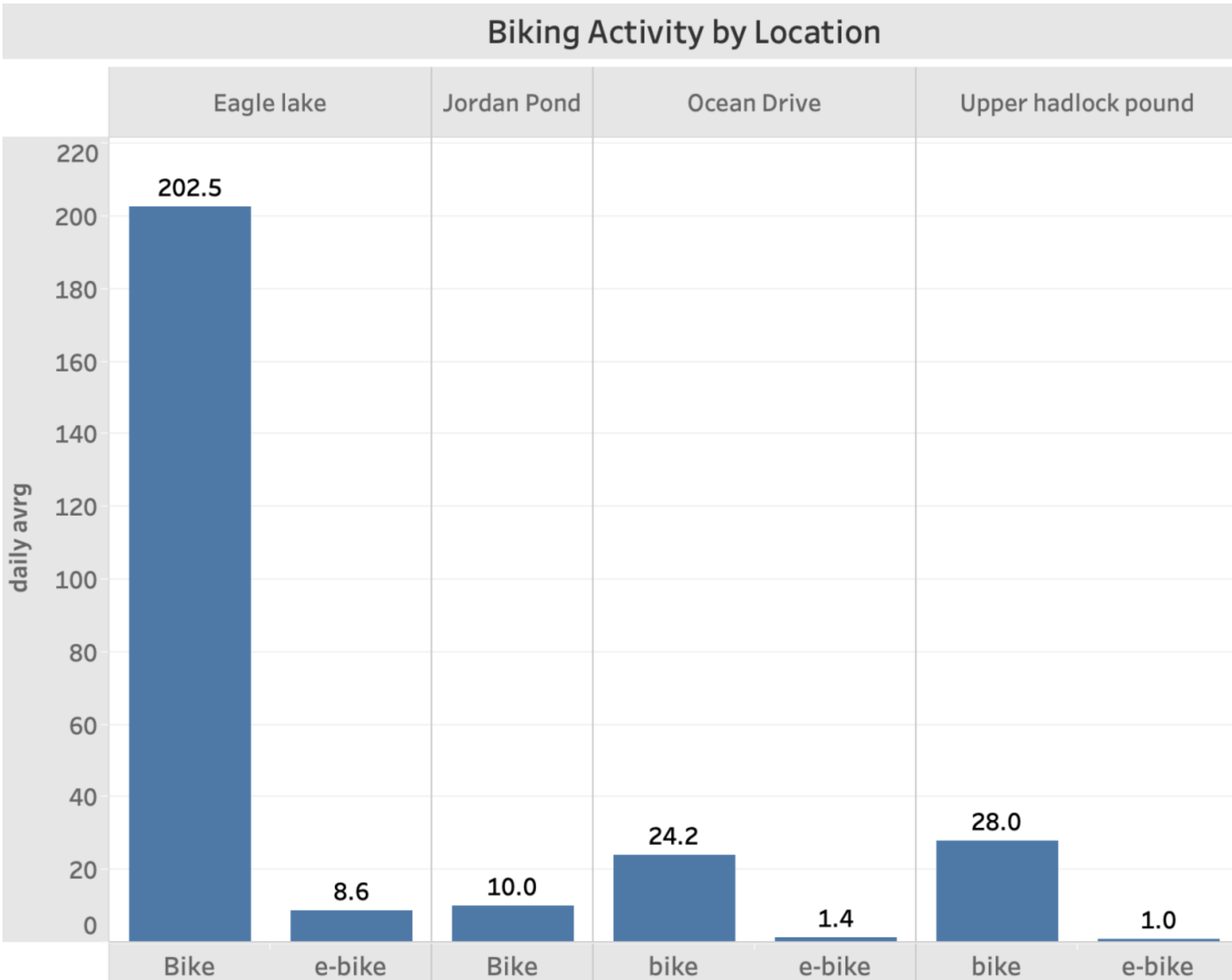
Appendix C: Helmet use vs. speed



Appendix D: Daily Biking Activity in Eagle Lake



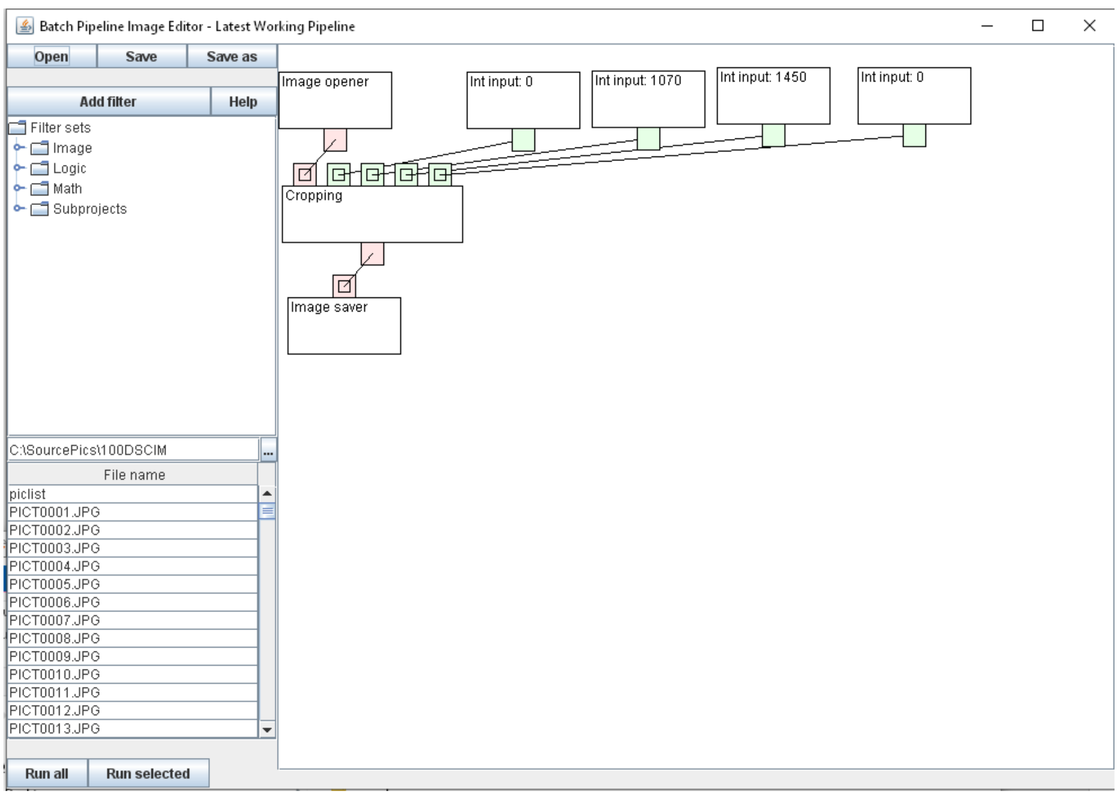
Appendix E: Biking Activity by Location



Appendix F: Data Cleaning Procedure

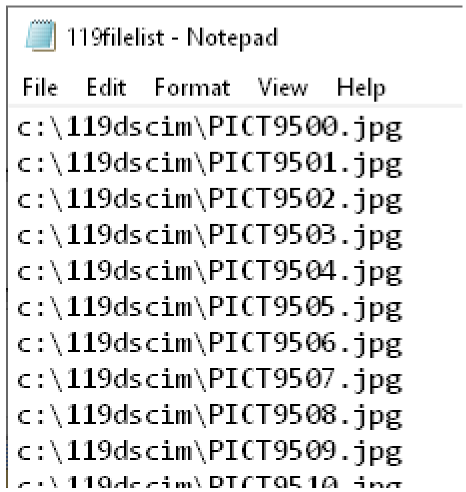
First, we put all the webcam images we wanted to analyze in a folder and ran it through BatchPIE, an open source image processing software(https://sourceforge.net/projects/batchpie/). We created an image processing pipeline in BatchPIE that cropped out the photo part of each image and left only the bottom components. The following image is an example of a processed webcam image.

Cropping the image significantly increased the accuracy of the Optical Character Recognition pipeline below.



This is a visual programming environment that lets you connect components that will execute commands. In the above case, Image Opener reads each image in the specified directory, feeds it through the cropping processor using the four input parameters which are coordinates, and puts the resulting picture into the directory of all cropped pictures.

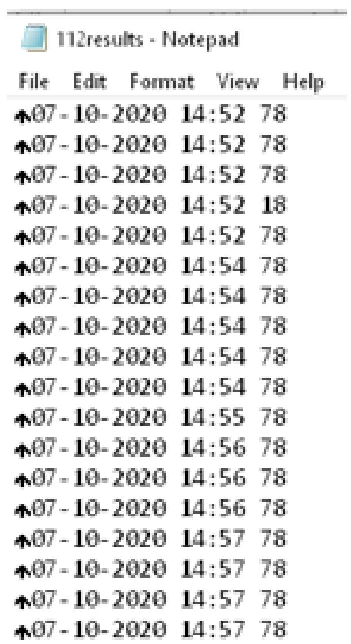
Next, we created a file list using MS DOS directory command that created an alphabetized list of all of the cropped images, directory by directory. The following image is an example of one of the file lists.


119filelist - Notepad

File Edit Format View Help

```
c:\119dscim\PICT9500.jpg
c:\119dscim\PICT9501.jpg
c:\119dscim\PICT9502.jpg
c:\119dscim\PICT9503.jpg
c:\119dscim\PICT9504.jpg
c:\119dscim\PICT9505.jpg
c:\119dscim\PICT9506.jpg
c:\119dscim\PICT9507.jpg
c:\119dscim\PICT9508.jpg
c:\119dscim\PICT9509.jpg
```

After testing a collection of Optical Character Recognition programs, we decided to use the java-based software Tesseract(https://github.com/tesseract-ocr/tesseract). We passed it the alphabetized list above and to get a list of OCR files, or names for each directory. The following image is an example of an OCR file list.


112results - Notepad

File Edit Format View Help

```
07-10-2020 14:52 78
07-10-2020 14:52 78
07-10-2020 14:52 78
07-10-2020 14:52 18
07-10-2020 14:52 78
07-10-2020 14:54 78
07-10-2020 14:54 78
07-10-2020 14:54 78
07-10-2020 14:54 78
07-10-2020 14:54 78
07-10-2020 14:55 78
07-10-2020 14:56 78
07-10-2020 14:56 78
07-10-2020 14:56 78
07-10-2020 14:57 78
07-10-2020 14:57 78
07-10-2020 14:57 78
07-10-2020 14:57 78
```

Then we imported those into excel for parsing. Using excel formulas, we were able to parse and extract the following relevant info.

File Name	Source OCR	Bike #	Place	Day of Week	Picture #	Date	Time	Incline	Temp (F)	Bil
PICT0029.JPG	□07-07-2020 06:36 38 59			Tuesday	0029	07-07-2020	06:36		59	
PICT0030.JPG	□07-07-2020 06:36 3859			Tuesday	0030	07-07-2020	06:36		59	
PICT0031.JPG	□07-07-2020 06:36 3859			Tuesday	0031	07-07-2020	06:36		59	
PICT0032.JPG	□(07-07-2020 06:37. ~'— 59			Tuesday	0032	07-07-2020	06:37		59	
PICT0033.JPG	□07-07-2020 06:37. ~'=~'— '59			Tuesday	0033	07-07-2020	06:37		59	
PICT0034.JPG	□(07-07-2020 06:37. ~'— '59			Tuesday	0034	07-07-2020	06:37		59	
PICT0035.JPG	□(07-07-2020 06:37. ~'— — ' 59			Tuesday	0035	07-07-2020	06:37		59	
PICT0036.JPG	□(07-07-2020 06:3[illegible] ~'— '*59			Tuesday	0036	07-07-2020	06:37		59	
PICT0037.JPG	□07-07-2020 06:39 59			Tuesday	0037	07-07-2020	06:39		59	
PICT0038.JPG	□07-07-2020 06:39 59			Tuesday	0038	07-07-2020	06:39		59	

The image above shows not all the Optical Character Recognition was clean, so we used the following excel formulas to extract the relevant info.

To extract the day of the week:

=CHOOSE(WEEKDAY(G103),"Sunday","Monday","Tuesday","Wednesday","Thursday", "Friday","Saturday")

To extract the date:

=CONCAT(RIGHT(LEFT(B103,FIND("-",B103)-1),2),"-",LEFT(RIGHT(B103,LEN(B103)-FIND("-",B103)),2),"-",MID(B103,FIND("~",SUBSTITUTE(B103,"-","~",2))+1,4))

To extract the picture number:

=LEFT(RIGHT(A103,FIND(".",A103)-1),4)

To extract the time:

=CONCAT(RIGHT(LEFT(B103,FIND(":",B103)-1),2),":",LEFT(RIGHT(B103,LEN(B103)-FIND(":",B103)),2))

To extract the temperature:

=RIGHT(B109,2)