Cadillac Mountain Reservation System

An Interactive Qualifying Project submitted to the Faculty of
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ABSTRACT:

In Acadia National Park, Cadillac Mountain has had problems accommodating the increase in visitors. In 2021, the National Park Service (NPS) implemented a reservation system that would help regulate the flow of visitors. A WPI Data Science Graduate team, in the spring of 2022, created a machine learning model that would predict the length of stay of visitors on the summit based on the weather. From the WPI model's predictions, the NPS could then adjust the number of reservations released for any specific day to optimize the summit parking lot. Examining any discrepancies between our observed dwell times and the model's predictions would show areas of limitations and need for further improvement.

ACKNOWLEDGEMENTS:

The success of this project can be greatly attributed to the continued input and support of many individuals. We would like to thank those who helped make this possible.

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EXECUTIVE SUMMARY:

INTRODUCTION:

The National Park Service (NPS) was created in 1916 with the mission to preserve and protect the national parks for future generations (Organic Act, 1916). The national parks became and have remained one of the most popular tourist destinations in the country. Acadia National Park is one of the most unique parks and was founded by private elitist landowners in 1901 in an effort to preserve the land. Cadillac Mountain, one of the main park attractions, is the highest point along the east coast of the US. The Summit Loop Road accesses the summit parking lot where visitors can stop and enjoy the beautiful views. However, due to the popularity of Cadillac Mountain, the summit parking lots can become full and cause a backup of cars along the summit road. In 2021, Acadia implemented a reservation system at Cadillac to manage the time and date in which visitors entered the park. Despite this, there are still times when there are more vehicles than spaces available. Our project team is trying to solve this problem by evaluating a model of visitor dwell time, created by a WPI project team, to optimize the reservation system.

BACKGROUND:

In 2016 the NPS recorded 330 million recreational visits across all national parks, a significant increase from previous years. However, the current park infrastructure (such as roads and parking lots) struggles to accommodate the large crowds. Many visitors travel through national parks in private vehicles causing roads to become blocked with traffic. This has a few different effects. First, it degrades visitors' experience and creates a safety hazard as emergency vehicles cannot travel quickly through the traffic. It also leads to illegal parking on road sides when there are more vehicles than parking spots.

Overcrowding negatively impacts the park environment in many ways. Visitors who wander off trail or park illegally trample fragile vegetation and soil. This leads to vegetation loss throughout the park (Manning, R 2009). Additionally, litter left on trails by visitors can be hazardous to wildlife (Siegler, K. 2021). Furthermore, pollutants and vehicle emissions in the parks contaminate water sources, harming both aquatic and land species (Sall et al., 2020). Traffic and congestion on the roads and parking lots increase carbon emissions, contributing to air pollution.

Overcrowding not only negatively impacts the environment of the park but also affects visitor experience. Group size, behavior, and perceived similarity to those around them can also impact visitors' perception of crowding (Manning, R 2009). Different strategies have been proposed to reduce overcrowding in national parks, such as implementing carrying capacities, reservation systems, public transportation, special use permits, and advertising lesser-known areas of the park (Timmons, 2019).

Congestion is a major issue in Acadia National Park, as it must accommodate the same number of visitors as Yellowstone, a park that is nearly forty times larger (Statista, 2022). Tracking congestion is a continuing problem for Acadia National Park as it is ungated and open to visitors. This allows people to roam in and out of the park through unmonitored entrances.

One of the most popular locations in Acadia is Cadillac Mountain. The summit can be reached via the Cadillac Summit Road or by hiking. There are two parking lots, the largest being the summit parking lot with 119 parking spots. The smaller lot, Blue Hill Overlook, is often used as overflow parking; however, most visitors will wait for a spot in the summit lot. During peak hours, the parking lots can fill, causing congestion and a queue of cars to form on the summit road.

In 2019, the NPS released the Acadia National Park Final Transportation Plan to address overcrowding and congestion. As part of the plan, the park considered increasing the management of Park Loop Road as well as establishing reservation systems at popular locations throughout the park. As of 2021, the NPS has fully implemented a reservation system for Cadillac Summit Road.

The NPS releases 30% of reservations ninety days before the date and the other 70% two days prior in 30-minute increments. The reservation system for Cadillac Mountain controls when visitors arrive; however, it does not dictate when they leave. This causes dwell time, the amount of time a vehicle spends on the summit, to fluctuate throughout the day, leading to increases in congestion.

To best assess this fluctuation in dwell times, a WPI graduate team analyzed historical data of the summit of Cadillac Mountain. The WPI project team modeled the data to predict the dwell times of vehicles. This model takes into account various factors such as temperature, wind speed, and time of year. This was completely generated with historical data gathered from StreetLight big data.

GOALS AND OBJECTIVES:

The primary goal of our project was to optimize the Cadillac Mountain Reservation System. To achieve our goal, we broke it down into three objectives. Our first objective was to determine the dwell time of vehicles and how dwell time fluctuates throughout the day. Next, our team analyzed the accuracy of the WPI project team model. Finally, we examined the visitor experience on the summit on Cadillac Mountain.

METHODOLOGY:

To determine the dwell time of vehicles on the summit, we directly observed when cars entered and exited the summit between the hours of 10:00am and 3:00pm. When a car entered the summit loop, we recorded the first four digits of their license plate along with the time of entrance; this process was repeated at the exit. We were then able to compare the license plates from the entrance and exit data to calculate the dwell time for each vehicle and the daily mean dwell time.

To predict the dwell time and volume for a specific day, weather conditions including temperature, humidity, wind, and rain were entered into a spreadsheet that was then uploaded to the WPI project team model. To determine the accuracy of the WPI model, we compared the model's predicted dwell time to our calculated daily dwell time. Metrics for the success of the model were determined by comparing the root square mean error (RSME) cited in the graduate team report with the RSME observed by our own data collection.

To examine visitor experience on the summit, we collected visitor opinions through surveys and captured people at one time (PAOT) photos. The surveys were available at two locations on the summit of Cadillac, one by the gift shop and the other at the summit overlook kiosk. The survey asked visitors to rate the quality of their experience, such as the amount of crowding experienced on the summit. To determine the number of people at one time (PAOT), photos were taken every half hour of the summit overlook and parking lot. The photos would then be compared with visitor's survey responses to view the amount of crowding that they actually experienced on the summit.

RESULTS AND DISCUSSION:

From our direct observations, we found the average vehicle dwell time to be 49.4 minutes. The lowest average daily dwell time was 20.7 minutes and the highest dwell time was 58.3 minutes. Compared to previous research, our average vehicle dwell time was significantly longer. The Resource Systems Group (RSG) in 2015 determined the dwell time to be 38.6 minutes. The WPI project team, on the other hand, found the dwell time to be 24.7 minutes. This difference could be caused by a few things. The first consideration is that the RSG conducted their research in 2015, prior to the implementation of the reservation system in 2021. Additionally, the WPI project team was not able to collect enough conclusive evidence due to the limitations of big data. Finally, while our research calculated an average vehicle dwell time, the dwell time calculated by both of these previous research studies was closer to a visitor dwell time. This difference is significant because the time that visitors interact with their car directly impacts the availability of the summit, but was not included in previous studies. Therefore, we believe that our dwell time is a more accurate representation of Cadillac Mountain's dwell time.

From our observations, we hypothesized that dwell time was influenced by the visibility on the summit. Compared to sunny days, the daily average dwell time on rainy and/or foggy days was lower. Two major components of visibility include cloud base and cloud cover, which measures the altitude of the cloud system and the total percentage of the sky covered by clouds, respectively. We found that all days with below average dwell time had a cloud base at or below the summit, causing the view of the summit to be obstructed.

While the WPI model made accurate predictions using their 2021 data, the data we collected showed longer dwell times than that predicted by the model with a consistent difference of about 22 minutes. The difference in calculated and predicted dwell times resulted from a few limitations in the WPI model. The first limitation was regarding StreetLight big data. The WPI project team only gathered data from pedestrian traffic and was not able to track vehicle patterns. The other limitation of the model resulted from inaccurate weather predictions and the lack of cloud variables in the model.

From our surveys, we found that 46.9% of respondents experienced 'little crowding', 48.1% experienced 'some crowding', and 5% experienced 'very crowded' conditions on the summit, as seen in figure 14. By comparing the results of our survey with the PAOT photos, we concluded that crowding was related more closely to the distribution of visitors rather than the number. Additionally, 1.6% of respondents found it to be extremely hard to find a parking spot compared to 49.6% of respondents who found parking to be easy. From the surveys, we were also able to determine that an average of 3.65 people arrived at the summit per private vehicle.

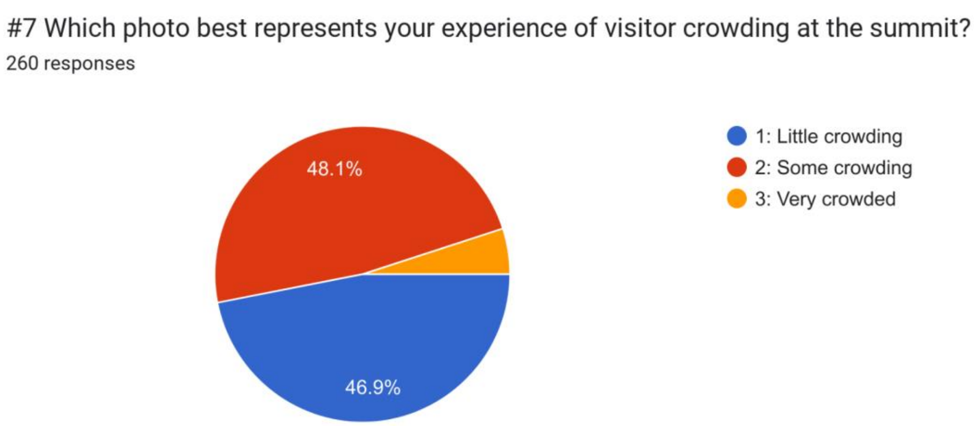


Figure 14: Visitor Survey Responses Graph

RECOMMENDATIONS:

Based on our findings, we came up with four recommendations to help optimize the Cadillac Mountain Reservation System. To improve the WPI project team model, we recommend that both cloud cover and cloud base be added to the model's weather input factors. Forecasts for both cloud base and cloud cover can be retrieved from Windy.com.

Additionally, we recommend that the park use traffic cameras to continue to track the dwell times of vehicles on the summit. Traffic cameras such as the Rekor Edge Pro, a commercial-grade camera from a computing company, can be used to capture the license plate and entrance time of the vehicle to calculate dwell time. By collecting data over a longer period of time, a more accurate dwell time can be calculated that better accounts for different weather conditions.

To prevent under or overcrowding on the summit, we recommend that the park use the WPI project team model. Once the model includes cloud base in its predictions, it will output more accurate data that can be utilized by the park to adjust the number of reservations released 48 hours before each -date. If the model predicted a large increase in visitors, then the park could reduce the number of reservations released. Similarly, the park could also release more reservations to allow more people to visit the summit if predicted dwell time is low.

For future IQP projects, we recommend focusing on visitor mobility and behavior on the summit. This data could be used to establish a carrying capacity for the summit of Cadillac Mountain and better optimize the summit area.

1.0.0 INTRODUCTION:

The National Park Service (NPS) was established in 1916 to preserve the natural and historic scenery of our national parks (Organic Act, 1916). Since the creation of Yellowstone National Park in 1872, the NPS has grown to cover more than eighty-four million acres (NPS, 2021). National parks range from military parks to urban preserves. The intentions for these parks vary from wildlife and ecology preservation to spectator scenery and recreational uses (Runte, A., 2010). Over the years, national parks have remained one of the most popular tourist destinations in the country, predicted to have a market size of nearly one billion dollars in 2022 (IBISWorld, 2021).

Acadia National Park was founded by private elitist landowners in 1901 in an effort to preserve the land. In 1919, Acadia was federally established as a government park. Due to its unique creation, about 25% of the land within Acadia is privately owned but still managed by the NPS (Hodge 2021). From its carriage roads to the Bass Harbor Lighthouse and Cadillac Mountain, Acadia is one of the most beautiful coastal parks. Cadillac Mountain is the highest point along the east coast of the US. Cadillac is also a subalpine environment. The federal government built the Cadillac Summit Road in 1939. This road accesses the summit parking lot where visitors can stop and enjoy the beautiful views. So many people visit the park that the summit parking lots often overflow. This leads to cars parking along the road, increasing congestion, trampling plants, and negatively impacting visitors' experiences.

In order to improve the visitor experience, many national parks are implementing the Visitor Experience and Resource Protection (VERP) plan. VERP is used to set indicators of quality where solutions are developed to maintain a positive visitor experience. In 2021, Acadia implemented a reservation system for Cadillac Mountain to manage the time and date in which visitors entered Cadillac Mountain's summit road. However, there are still times when there are more visitors than spaces available. Our project team is trying to solve this problem by evaluating a model of visitor dwell time, created by a WPI project team to optimize the reservation system.

2.0.0 BACKGROUND:

Recently, overcrowding has become a major issue for the NPS as it negatively impacts the park environment and visitor experience. In an attempt to solve this issue, the NPS has implemented reservation systems to manage and decrease overcrowding.

The background sections below will describe relevant factors in assessing positive visitor experience at Cadillac Mountain. Additionally, the Cadillac reservation system, congestion on Cadillac, the greater Acadia National Park, and the greater parks system will also be discussed.

2.1.0 CONGESTION IN NATIONAL PARKS:

In 2016, the NPS recorded over 330 million recreational visits, the largest ever recorded (US DoI, 2018). As the number of visitors continues to increase, the current park infrastructure (such as roads and parking lots) struggles to accommodate the large crowds. Congestion can negatively impact the environment and the visitors' experience.

2.1.1 PARKING IN THE PARKS:

Since many visitors travel through national parks in private vehicles, roads can become blocked by traffic. In addition to worsening visitors' experience, traffic can cause safety issues when emergency vehicles cannot travel the park roads quickly. Similarly, there are not enough parking spaces for all vehicles, leaving roads backed up as people wait for spaces to open up (Deseret Morning News October, 2021). Throughout the national parks, many people may park their vehicles illegally on the sides of roads. Most park officials oppose the idea of expanding parking lots because it would conflict with the NPS mission of preserving and protecting park resources (Trotter, 2015). In response to increased visitor frustration with parking, the NPS has set aside additional staff to help visitors find parking and has encouraged the use of public transportation (Timmons, 2019).

2.1.2 EFFECTS ON THE LAND:

In addition to overwhelming park infrastructure, overcrowding can also negatively impact the park environment. Due to the overcrowding of national parks, some visitors wander off designated trails, trampling fragile vegetation and soils. This results in an expansion of vegetation loss along trails (Manning, R 2009). Similarly, people who illegally park can also damage vegetation depending on where they park their vehicles. Increased visitation has also resulted in larger amounts of litter and waste being left in the park. In Yosemite and Zion National Park, park rangers reported an increase in human feces, toilet paper, and litter being left on trails (Siegler, K. 2021). Litter can be hazardous to wildlife, as they can become trapped or entangled. These pollutants and vehicle emissions in the parks also contaminate water sources, which harms both aquatic and land species (Sall et al., 2020). Traffic and congestion on the roads and parking lots also increase carbon emissions, contributing to air pollution and climate change.

2.1.3 EFFECTS ON VISITOR EXPERIENCE:

Overcrowding not only negatively impacts the environment of the park but also affects visitor experience. Visitor Experience and Resource Protection (VERP) can be used to assess a visitor's experience by establishing a standard of quality, such as a specific number of people at one time (PAOT) (Manning, R 2009). For an overview of VERP, reference Appendix A. Overcrowding can negatively impact the standard of quality, specifically when visitors encounter more people than expected. Many visitors come to national parks to experience the "calming and peaceful" effects of nature, and overcrowding decreases this sensation (Bullock, S 2007). A variety of factors have been found to influence people's perception of crowding: characteristics of visitors, characteristics of those encountered, and situational variables (Manning, R 2009). Some visitors prefer there to be fewer people around them, while others feel that contact with other visitors enhanced their experience. Group size, behavior, and perceived similarity to those around them can also impact visitors' perception of crowding (Manning, R 2009).

Different strategies have been proposed to reduce overcrowding in national parks, such as implementing carrying capacities, reservation systems, public transportation, special use permits, and advertising lesser-known areas of the park (Timmons, 2019). Since the summer of 2021, reservation systems have been implemented in Acadia, Glacier, Haleakala, Zion, Yosemite, and Rocky Mountain National Parks (Carey, April 2021). Each national park has implemented slightly different reservation systems. Some parks only require reservations at popular sites, while other parks (such as Yosemite National Park) require a reservation to enter the park (Carey, April 2021).

2.2.0 CONGESTION IN ACADIA:

Congestion has been extremely prominent in Acadia National Park and has affected visitor experience. To put it in perspective, Acadia must accommodate the same number of visitors as Yellowstone, a park that is nearly forty times larger than Acadia (Statista, 2022). Efforts to track and manage this congestion have been made; however, it has proven to be more difficult than expected.

2.2.1 TRAFFIC TRACKING DIFFICULTIES:

One major problem with tracking visitors from Acadia is that the number of visitors is probably higher than the number recorded by the NPS. This is because Mount Desert Island (MDI) is ungated and open to guests and locals. People can roam in and out of the park at their leisure without paying the entrance fee. A popular site in Acadia is Park Loop Road, a 27-mile scenic road along the east side of MDI, which has seven entrances that are predominantly unmonitored. A WPI project team in 2016 tracked the number of cars that entered Park Loop Road and found that on average, roughly 2.8 million cars entered per year (Leahy, Whittle, Dziuban, et al., 2016). This study helped park rangers determine heavy traffic areas and identify peak traffic times, allowing them to better monitor entrance fees.

In addition to counting the number of cars, another WPI project team in 2018 tracked visitors via a GPS system to gather data on visitor sites and times (Fischler, Nadeau, Charbonneau, et al., 2018). This data helped park rangers see what locations were popular among visitors and allowed them to cross-reference the areas and times with weather patterns, cruise schedules, and holiday impacts. The information from these two teams helped Acadia determine what places were the most popular and how many people visited, but did not focus on specific destinations.

2.2.2 LACK OF INFRASTRUCTURE:

While Acadia is trying to manage the increase in visitors and still provide the same quality of visitor experience, they simply do not have enough infrastructure to do so. Parking lots at prime tourist locations in Acadia, such as Cadillac Mountain and Sand Beach, fill up fast and visitors end up illegally parking on the side of the road to find a spot. However, this backs up traffic along the roads, worsening the visitors' experience. Over the past five years, the NPS has worked in Acadia to reduce overcrowding, parking, and traffic problems. One proposed solution was to prohibit private vehicles; however, the public was not receptive to this idea because it affected their own personal freedoms (Hodge 2021). The NPS also implemented a propane-powered bus system called the Island Explorer to encourage people to take public transportation rather than private vehicles. The Island Explorer travels throughout MDI and is a free public transportation service, although a ticket is required if entering Acadia National Park. The Island Explorer was established in 1999 and in the first year alone replaced 43,000 cars that would have caused congestion and released an estimated two tons of pollutants. In 2001, 200,000 passengers rode the Island Explorer, 22% of whom were MDI residents, which helped reduce carbon emissions by 33% (Acadia's Island Explorer Shuttle 2021). While the Island Explorer travels to and from many popular tourist locations, they do not provide tours or operate on Cadillac Mountain (Island Explorer Home, n.d).

2.3.0 CONGESTION ON CADILLAC MOUNTAIN:

Cadillac Mountain is one of the most popular tourist spots in Acadia National Park. Not only do people like to hike and enjoy the view, but it is also the prime spot to watch the sunrise and sunset. The summit can be accessed via three hiking trails in addition to the Cadillac Summit Road, a thin and winding road that is primarily driven by cars as private vehicles over twenty-one feet long are prohibited (NPS, 2022). Cadillac Mountain offers two parking lots, one on the summit of the mountain and a smaller parking lot facing the west called the Blue Hill Overlook (Figure 1). On the summit, there are spots for 119 personal vehicles and 6 tour buses. The Blue Hill Overlook parking lot contains thirty-eight more parking spaces. This parking lot is farther down the mountain and can be used for car overflow. However, most visitors prefer the summit lot and circle there waiting for a spot (Friends of Acadia 2017). When the mountain becomes crowded, especially during the summer months, both parking lots become full and congested with people and cars.

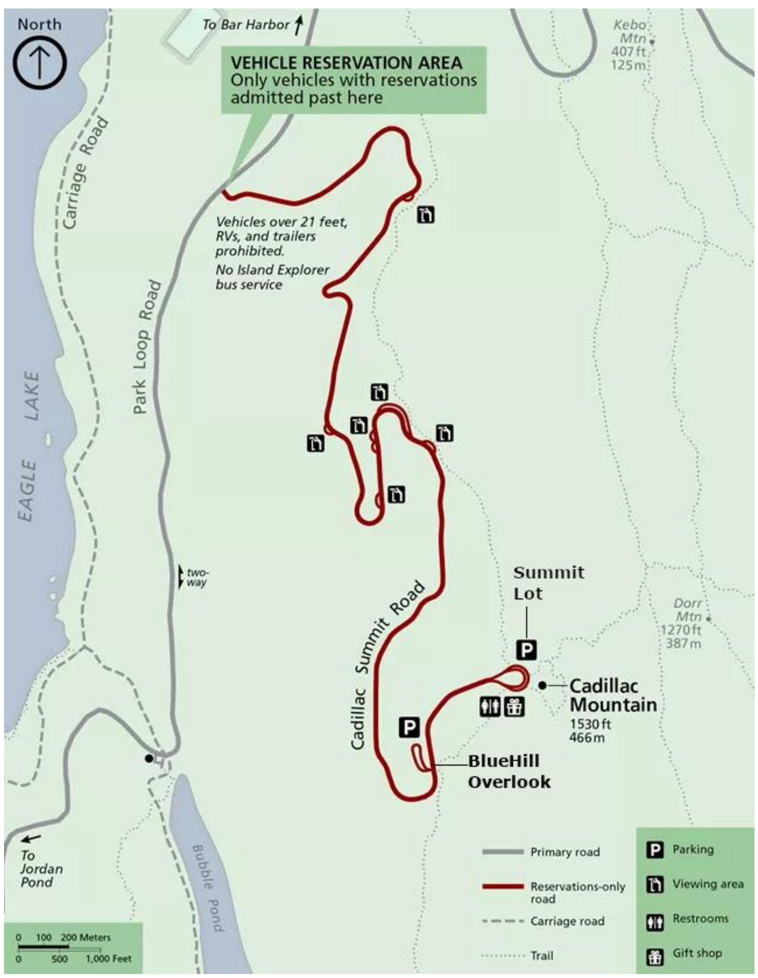


Figure 1: Map of Cadillac Summit Road and Parking Areas (NPS, 2022)

2.4.0 MANAGEMENT OPTIONS FOR CADILLAC MOUNTAIN:

In 2019, the NPS released the Acadia National Park Final Transportation Plan which proposed four alternative strategies to address transportation and congestion issues. "Alternative A" proposed that no changes would be made to the park, while alternatives B through D outlined different courses of action. "Alternative B" would establish a parking reservation system at Cadillac Mountain, Sand Beach, Thunder Hole, Jordan Pond House, and Sieur de Mont. "Alternative D" involved management of the entire Park Loop Road. The NPS preferred "Alternative C", which would implement timed entry reservation systems at Ocean Drive corridor, Cadillac Summit Road, and the Jordan Pond House North Lot (NPS, 2019). However, the reservation system at Ocean Drive was removed as it only escalated traffic. As of 2021, the NPS has fully implemented a reservation system for Cadillac Summit Road (Carey, 2021).

2.4.1 CADILLAC RESERVATION SYSTEM:

Reservations on Cadillac Mountain dictate the time at which the visitors arrive; but do not dictate the time the visitor leaves or the space they park. A study by the Resource Systems Group (RSG) found that the average vehicle length of stay in either parking lot was over thirty minutes, as seen in table 1. Since there are different amounts of traffic throughout the day and the week, parking spaces can run out at different times. Another study on vehicle traffic on the mountain found that it was the busiest for sunrise and sunset (Jacobi, C, 2017). As shown in table 2, throughout the day, the number of cars per hour fluctuates greatly. This may also be correlated to a change in vehicle dwell time, or the amount of time that vehicles spend on the summit. Moreover, the Blue Hill Overlook is the most popular during sunset despite having a smaller parking lot (RSG, 2017). All of this makes it very difficult to ensure there are enough spaces at any given time.

Table 1: Mean Private Vehicle Dwell Time (Minutes) in Parking Lots (RSG, 1/27/2017, p#21.)

DATA SOURCE	MEAN	STANDARD DEVATION
Route Survey Cards	26.2	13.7
Model Calibration	38.6	1.75

Table 2: Design Day Hourly Private Vehicle Arrivals, Cadillac Mountain (RSG, 1/27/2017, p#16.)

HOUR	CADILLAC MOUNTAIN ROAD (PRIVATE VEHICLES)
12:00 AM – 1:00 AM	6
1:00 AM – 2:00 AM	5
2:00 AM – 3:00 AM	7
3:00 AM – 4:00 AM	22
4:00 AM – 5:00 AM	172
5:00 AM – 6:00 AM	100
6:00 AM – 7:00 AM	6
7:00 AM – 8:00 AM	14
8:00 AM – 9:00 AM	42
9:00 AM – 10:00 AM	108
10:00 AM – 11:00 AM	188
11:00 AM – 12:00 PM	222
12:00 PM – 1:00 PM	179
1:00 PM – 2:00 PM	152
2:00 PM – 3:00 PM	183
3:00 PM – 4:00 PM	144
4:00 PM – 5:00 PM	129
5:00 PM – 6:00 PM	124
6:00 PM – 7:00 PM	189
7:00 PM – 8:00 PM	139
8:00 PM – 9:00 PM	34
9:00 PM – 10:00 PM	31
10:00 PM – 11:00 PM	17
11:00 PM – 12:00 AM	8
Total: 24-Hour/8 AM to 5 PM	**2221/1347**

The Cadillac Reservation System is best understood by looking at figure 2. In figure 2, you will notice that the reservations are booked every half-hour, from 6:00 am to 8:00 pm for a daytime reservation. The reservation system is only in effect during the summer months; from May 25 until October 22. Currently, the system releases 30% of available passes ninety days before the day of their reservation. The other 70% are released two days before.

Figure 2. Reservation Web Portal (2022)

While visitors are required to check in during their specific entry window, there is no specified departure time (NPS, 2022). The problem with this model is that visitors can stay and park their car at the summit for as long as they like, leading to varying dwell times. With a limited number of parking spots available, people attempt to park along the summit road (NPS, 2016). The park can control when drivers come to park through the current model, but is unable to force them to leave, resulting in an inconsistent departure time.

2.4.2 MODELING VISITOR DWELL TIME:

To best assess the fluctuation of dwell times, the data from Cadillac Mountain's reservation system was sent to a WPI graduate team of data scientists for analysis. This data kept track of the number of tickets available, the number of tickets sold, what type of ticket the visitor purchased, the time they purchased it, and their check-in time. This data also sheds light on times that the mountain was most popular and when congestion was the worst. This WPI project team modeled the data to better understand the dwell time of vehicles. In addition, they have collected historical data about the weather, traffic patterns, and congestion levels. They created a model that can predict how long vehicles will stay at the summit based on specific conditions and time of the year. The list of factors is available in table 3.

Table 3. List of factors considered by the model (Kelly et al., 2022)

1. Month
2. Year
3. Season
4. Average Daily Temperature
5. Average Daily Heat Index
6. Minimum Temperature
7. Maximum Temperature
8. Average Air Pressure
9. Average Humidity
10. Average Rainfall per Hour
11. Average Wind Speed
12. Average Wind Gust

3.0.0 METHODOLOGY:

The goal of this project was to optimize the Cadillac Mountain Reservation System. To optimize the reservation system, the summit would ideally be able to accommodate as many people as possible without exceeding the number of available parking spaces (A. Gibson, personal communication, June 21, 2022). In order to achieve this, we broke down our objectives into three main points:

1. Determine the dwell time of vehicles and how it fluctuates throughout the day
2. Analyze the WPI project team model
3. Examine the visitor experience on the summit of Cadillac Mountain

*3.*1.0 *VEHICLE DWELL TIMES:*

The measure of dwell time, or the amount of time vehicles spend in the summit parking lot, is a major metric that was needed to produce an effective reservation system. Dwell time is not fixed and can fluctuate based on person, group size, weather, and other factors. We only gathered data at the summit parking lot; we did not look at the Blue Hill Overlook. We also focused on vehicle dwell time as it contributed to the carrying capacity of the summit parking lot.

3.1.1 DIRECT OBSERVATION:

We directly observed cars as they entered the summit parking lot between the peak visitor hours of 10am to 3pm. When a car entered the loop, we recorded the first four digits of the license plate as well as the time they entered. This process was repeated at the exit (Figure 3). At the end of the day, we were able to compare license plates from the entrance data and the exit data and calculate the dwell time for each vehicle. We calculated the dwell time via a custom code shown in Appendix B. These dwell times were averaged throughout the day to find daily mean dwell times. Tour buses and park vehicles were excluded from the dwell time analysis as they had their own marked spaces.

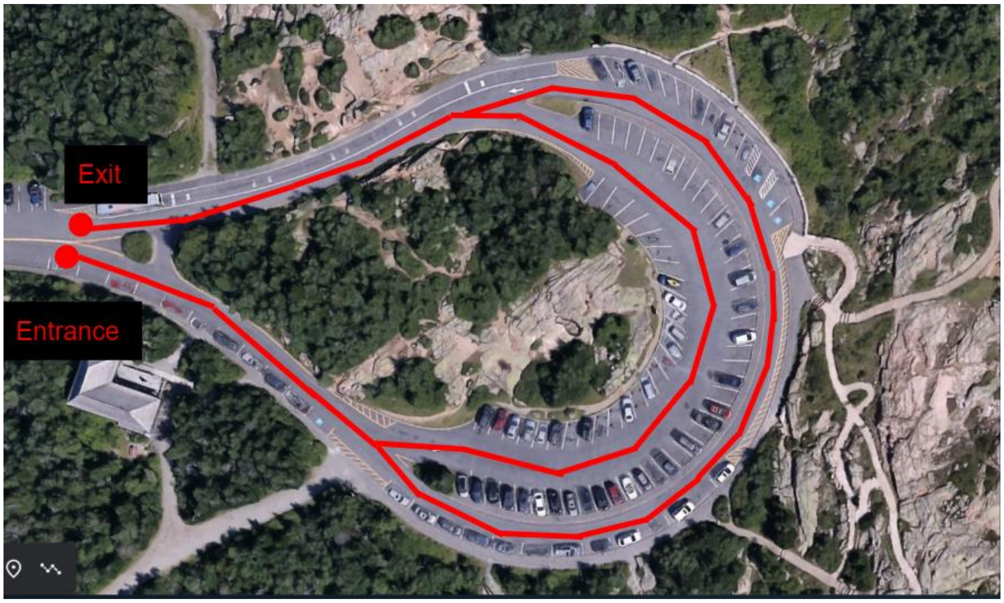


Figure 3: Summit Parking Lot at Cadillac Mountain (Google Earth, 2022)

3.2.0 WPI GRADUATE TEAM MODEL:

A WPI project team created an application that used historical weather data to predict the dwell time of visitors (Kelly et al., 2022). The model could then be used by the park to optimize the reservation system by adjusting the number of reservations made available and in turn prevent under or overcrowding of the summit parking lot. This project was done remotely and must be verified through direct observation on the summit of Cadillac Mountain before it can be implemented.

3.2.1 USING THE WPI PROJECT TEAM MODEL:

To predict the dwell time and volume for a specific day, weather conditions including temperature, humidity, wind, and rain are entered into a spreadsheet. The spreadsheet would then be uploaded to a web application, where it could be used to interface with the model and predict the average dwell time for each day. Although there were some issues in the operation of the web application, the source code is publicly available. This source code was able to be run locally on a laptop.

3.2.2 ASSESSING THE ACCURACY OF THE WPI PROJECT TEAM MODEL:

To assess the accuracy of the WPI project team model, we collected daily weather and dwell time data and compared it to the model's predictions. This on-the-ground verification was done the same way that has been outlined above, observing the dwell time of cars to help forecast the number of reservations that should be released per half-hour. In addition to observing dwell time, the weather conditions were collected from Visual Crossing Weather Service. From here, we used our collected dwell times and compared them to the prediction made by the WPI project team model. Metrics for the success of the model were determined by comparing the root square mean error (RSME) cited in their report with the RSME observed by our own data collection. RSME is a measure of error that is an accumulation of the difference between the predicted value and the observed error.

3.3.0 VISITOR EXPERIENCE:

To examine visitor experience and vehicle use patterns on the summit, we collected visitor opinions through surveys, captured people at one time (PAOT) photos of the summit, and analyzed park vehicle counts. Based on vehicle use patterns and perceived crowding on the summit, these results can be used to adjust the number of reservations released.

3.3.1 SURVEYS:

We carried out surveys at two locations on the summit, one by the summit gift shop and one on the summit overlook kiosk. Visitors could scan a QR code that took them to an online form. The QR codes were left on the summit at all times, so that visitors could complete the survey at any time during the day.

The survey asked visitors to describe the details of their reservation and to rate the quality of their experience (Table 4). To address the impact of the reservation system on visitor experience, visitors were asked to rate the difficulty of finding a parking spot on the summit. As used in VERP (Appendix A), ratings were given on a sliding scale from 1 to 5 (Manning, R 2009). Additionally, visitors were asked to select the photo where they would have the best experience on the summit (Figure 4). Using the same photos, visitors were then asked to select the photo that best represented the amount of visitor crowding they experienced on the summit. Finally, visitors were asked to rate the overall level of crowding that they felt on the summit.

Table 4. Example Survey for Visitors on the summit.

Question	Answer
How did you arrive at the summit?	▢ Hiked ▢ By private vehicle ▢ By bus
How many people (including yourself) arrived in your vehicle?	#__________
How early did you book your reservation?	▢ More than 3 days early ▢ 3 Days or less
What time did you book your reservation for?	▢ 06:00 ▢ 07:00 ▢ 08:00 ▢ 09:00 ▢ 10:00 ▢ 11:00 ▢ 12:00 ▢ 13:00 ▢ 14:00 ▢ 15:00 ▢ 16:00 ▢ 17:00 ▢ 18:00 ▢ 19:00 ▢ 20:00
	▢ :00 ▢ :30
Please rate the difficulty of finding a parking spot at the summit of Cadillac Mountain	▢ 1 (Easy/ Little Crowding) ▢ 2 ▢ 3 ▢ 4 ▢ 5 (Difficult/ Very Crowded)
Please select the photo you would have the best visitor experience	▢ 1 (Little Crowding) ▢ 2 (Some crowding) ▢ 3 (Very crowded)
Which photo best represents your experience of visitor crowding at the summit?	▢ 1 (Little Crowding) ▢ 2 (Some crowding) ▢ 3 (Very crowded)
Please rate the level of crowding you felt while you were on the summit today	▢ 1 (No crowding) ▢ 2 ▢ 3 ▢ 4 ▢ 5 (Too Crowded)

Little Crowding *Some Crowding* *Very Crowded*

Figure 4: Images used in survey

To best analyze the data collected through these surveys, we did not include any open-ended responses so that patterns were more easily noticed. After collecting the data, the frequency of each response was determined.

3.3.2 PEOPLE AT ONE TIME:

To determine the number of people at one time (PAOT) on the summit, photographs were taken every half hour between 10:00am and 3:00pm. The photographs were taken from the same location and covered the parking lot and areas of the summit loop trail (Figure 5).

Figure 5. Photographs of the parking lot and summit loop trail

We analyzed visitor experience data from the surveys using the objective PAOT photos from the summit. Using the timestamp from the survey, we examined our PAOT photos at that time to see the level of visitor crowding they experienced. This method helped us recognize the range of visitor perceptions of crowding.

3.3.3 PARKING DATA FROM FRIENDS OF ACADIA:

The number of cars driving up the summit was automatically counted before the entrance of the Blue Hill Overlook using pneumatic sensors. These sensors detected when a car passed over them, and counted the number of cars entering or leaving. In the end, data that indicated entering and exiting cars over the weeks of observation were graphed to visualize the peak hours of the day. We tested this method of visualization on data received by the NPS from the 2021 season and yielded charts that appear in figure 6. The purpose of this kind of analysis was to determine vehicle patterns throughout the day during the summer months.

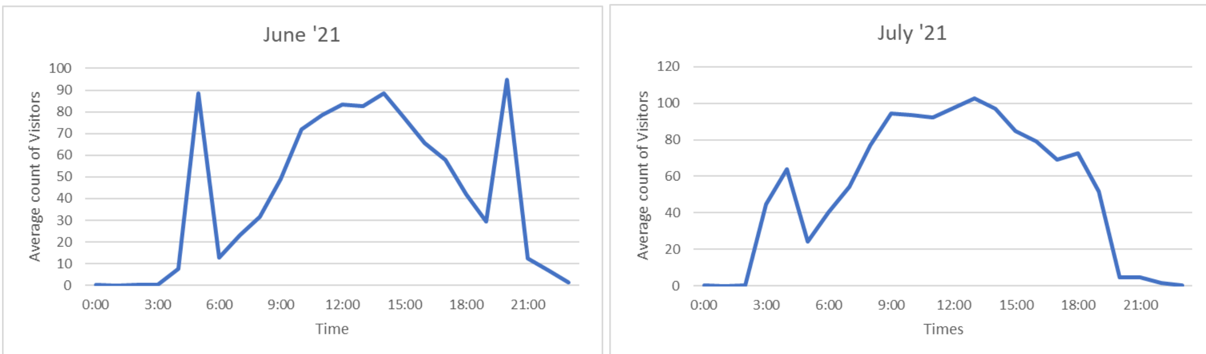


Figure 6. The Average Count of Visitors on the Summit in June and July, 2021

3.4.0 ETHICS:

Our project was sponsored by Worcester Polytechnic Institute and was in fulfillment of the graduation requirement of the Interactive Qualifying Project. When surveying visitors, they only had to answer the questions that they were comfortable with, could leave any or all sections blank, and were informed that they would remain anonymous. Due to the use of human subjects, an IRB exemption was completed.

3.5.0 TIMELINE:

Below is a Gantt chart of a seven-week breakdown for collecting and verifying data for the Cadillac Mountain Reservation System (Figure 7).

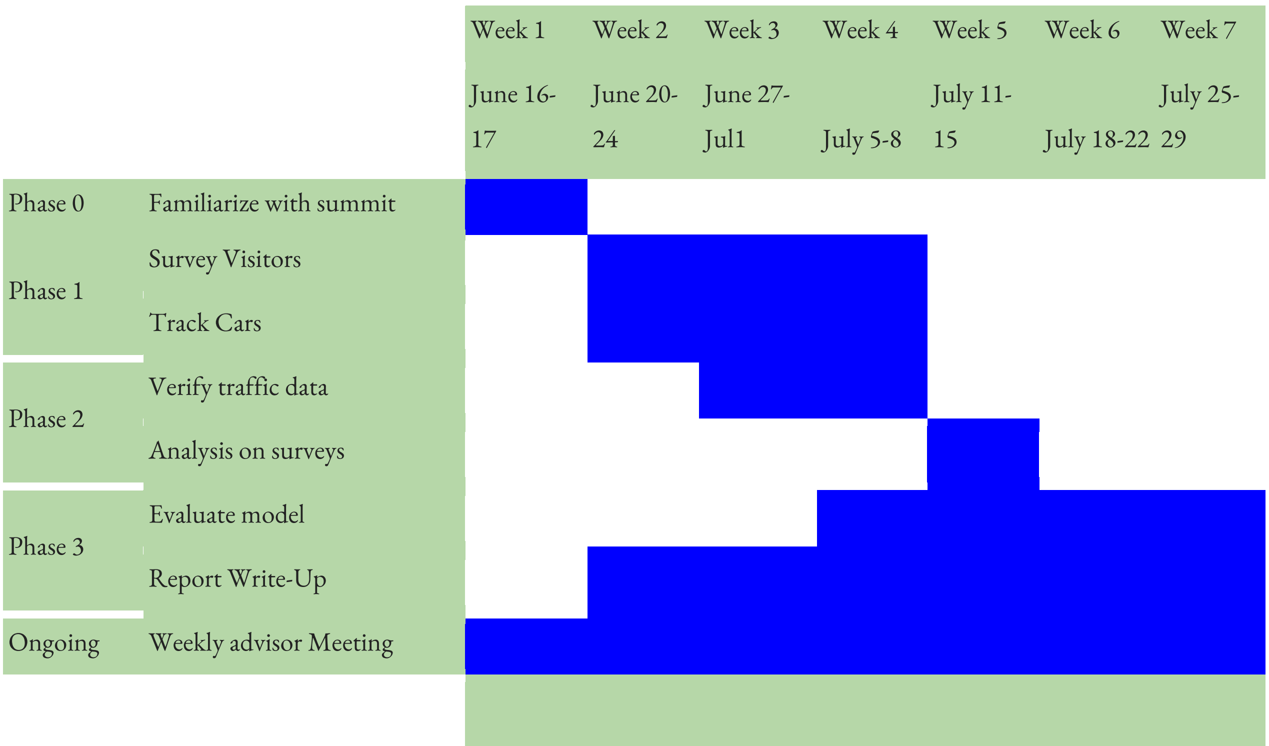


Figure 7. Gantt chart timeline of collecting data

4.0.0 RESULTS AND DISCUSSION:

Through direct observation of dwell times and surveys, we drew conclusions about visitors' behaviors and activities on the summit in order to improve the reservation system. We did this through four steps. First, we compared our method of data collection with past studies to evaluate the accuracy of our dwell time. From our data, we were then able to observe a correlation between weather and vehicle dwell time on the summit. From this correlation, we found limitations within the WPI project team model. We concluded our research by sifting through visitor responses from our survey to gauge visitor opinions on the summit.

4.1.0 DIFFERENT METHODS OUTPUT DIFFERENT DWELL TIMES:

Our study found the average vehicle dwell time to be 49.4 minutes. The lowest average daily dwell time was 20.7 minutes and the highest dwell time was 58.3 minutes. While our study used direct observation, other studies used methods such as route survey cards and big data. We then compared our average dwell time and vehicle counts with previous research.

A similar study was conducted by RSG in 2015 using route survey cards to calculate the average dwell time. The cards were distributed for three days between the hours of 8:00 am and 5:00 pm. The RSG team found the mean dwell time to be 26.2 minutes (Table 5). Even their calibrated model, which modified the dwell time for consistency using previous research, found the mean to be 38.6 minutes. The difference in dwell times, particularly compared to the RSG study, could be caused by a few reasons. The first is the difference in data collection time. Our study focused on the peak hours of the day while the RSG study included a larger range of times. In addition, the RSG study focused on visitor dwell time, rather than vehicle dwell time. The last consideration is that the RSG conducted their research prior to the implantation of the reservation system.

The WPI project team, using big data from StreetLight during the summer of 2021, concluded that the average dwell time was about 24.7 minutes (Kelly et al., 2022). This lower dwell time can also be associated with a couple of factors. The first is that StreetLight did not provide a lot of conclusive evidence due to the limitations of big data. Similar to the limitations of the RSG study, the WPI project team looked at the dwell time of visitors, rather than vehicle dwell time, which excluded a significant amount of dwell time from their data. A summary of each study and its calculated dwell time and limitations can be seen in table 5.

Table 5: Table of varying studies and their calculated dwell times

Study (Year of Collection)	Dwell Time	Limitation
RSG (2015)	26.2 minutes (calculated) 38.6 minutes (calibrated)	1. Prior to implementation of the reservation system 2. Examined visitor dwell time rather than vehicle dwell time 3. Time range
WPI Project Team (2021)	24.7 minutes	1. Limitation from big data 2. Examined visitor dwell time rather than vehicle dwell time
Our Data (2022)	49.4 minutes	1. Human error

4.2.0 FACTORS THAT AFFECT AVERAGE DWELL TIME:

When determining dwell time, there were a couple of factors to consider. From our observations, we found that visibility on the summit influenced dwell times.

4.2.1 VISIBILITY:

There is a sizable difference in the dwell time between days with varying weather conditions. For example, in the figures below (Figure 8 and Figure 9) there is a sixteen-minute difference in the dwell time. Our data indicated that weather conditions most seen as negative, such as rain or fog, showed greatly reduced dwell times. We saw some visitor dwell times as short as 8 minutes in rainy conditions. Conditions most seen as positive, such as clear or sunny, showed a much longer dwell time. Some cars stayed longer than 70 minutes.

Figure 8: Summit on a sunny day
(Dwell time: 58 minutes)

Figure 9: Summit on a foggy morning
(Dwell time: 42 minutes)

4.2.2 CLOUD VARIABLES:

We hypothesized that visibility was a major influence on dwell time. The biggest contributor to visibility was cloud cover and cloud base. Cloud base is defined as the altitude of a cloud system and cloud cover is the total percentage of the sky covered by clouds (Merriam-Webster). We were able to estimate the cloud base using the equation shown below (Table 6). To calculate this estimation, we used data from Visual Crossing Weather service. We found that every day with a below-average dwell time had a cloud base near or below the summit of Cadillac Mountain, therefore obstructing the view. For example, on a rainy day, our average dwell time was 20.75 minutes and the cloud base was 886 ft. This is significantly lower than Cadillac's 1527 ft summit. Due to this, we believe that cloud base and other cloud variables are vital for accurate dwell time prediction.

Table 6: $$\text{Cloud Base } (height) = \frac{(\text{Average Temperature} - \text{Average Dew Point})}{4.4} * 1000$$

All measurements were in imperial units. (United States, 2008)

4.3.0 WPI PROJECT TEAM MODEL:

The WPI project team had set out to predict dwell times based on the day of the week, month, year, and various weather factors (Kelly et al., 2022). The WPI model was accessed via a Jupiter notebook, which is a web-based interactive computer development platform. The source code is available on the team's github repository.

4.3.1 PREDICTED DWELL TIME:

The WPI model made extremely accurate predictions using their 2021 data as seen in figure 10. As seen in this graph, the green line depicts the predicted dwell time from the model and the red line shows the actual dwell time from the StreetLight data. On average, the predicted dwell time was 30.7 minutes. However, we can see that the extremes of the actual dwell time stray far off the model's predictions of dwell time.

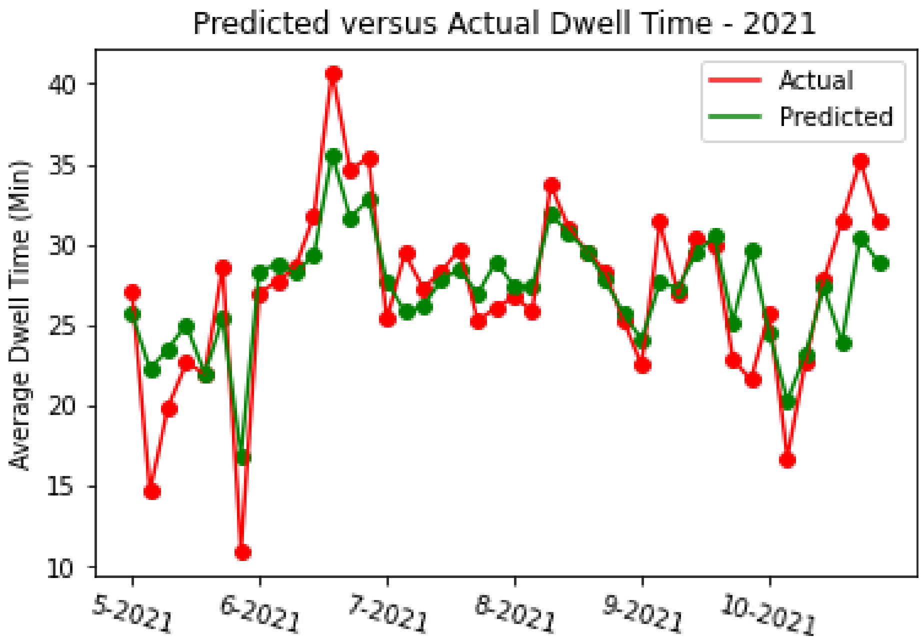


Figure 10: Graph of model performance by the WPI project team model (M. Kelly, et al., 5/3/2022, p#23.)

The data we collected showed longer dwell times than that predicted by the model, with an average difference of about 22 minutes. As shown in figure 11, the red line depicts the dwell time that we observed on the summit. The green line depicts the dwell time the WPI model predicted. Within our dataset, there was one day of significant rainfall, and we noticed a 58% reduction in the average time vehicles stayed on the summit. Additionally, there was a 64% reduction in dwell time compared to a warm sunny day. This was not reflected in the WPI project team model and led us to believe there were limitations in their methods of data collection.

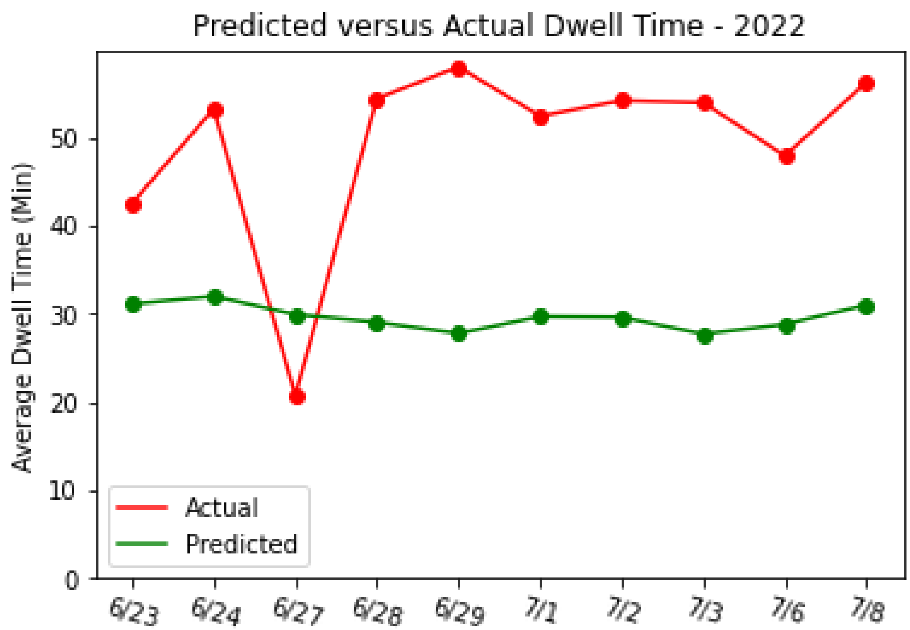


Figure 11: Observed dwell time vs Actual time

4.3.2 LIMITATIONS:

The current discrepancy in the WPI project team model stems from a few limitations. The first is the limitations of big data collection. The WPI project team sought to capture the vehicle length of stay, but only gathered data on the summit for areas with pedestrian traffic (Figure 12). This removes much of the time that visitors would spend on the summit, including interacting with their vehicle and leaving to go for a hike.

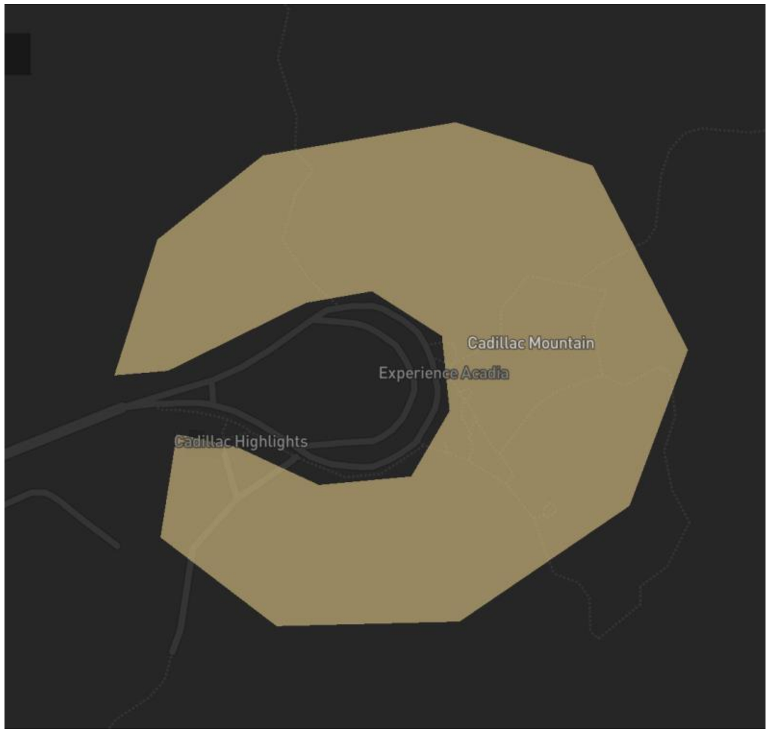


Figure 12: Area measured for dwell time by the WPI project team model

Additionally, dwell times longer than one hour were removed, even though the average dwell time that we collected hovered in the 50-minute range, and 34% of all stays were above one hour. When we followed the same criteria, our dwell time related more closely to the predicted dwell time (Figure 13).

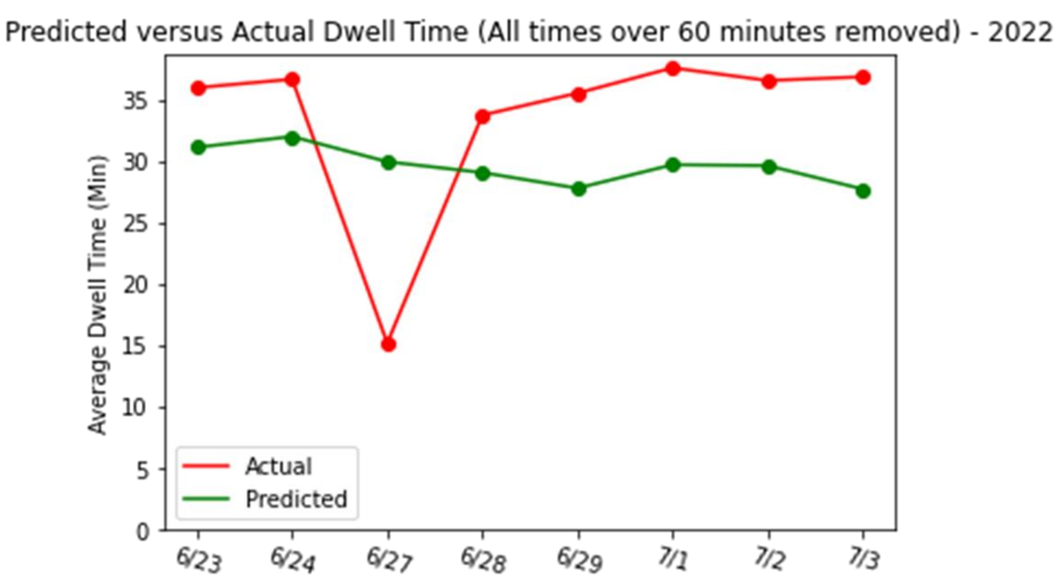


Figure 13: Predicted vs. actual dwell time (60 minutes removed)

Further, the WPI project team model is limited to the accuracy of the weather predictions. The WPI model used weather forecasts from Weather Underground Bar Harbor to predict dwell times. This is very important as the weather on Cadillac Mountain is frequently different from the weather at Bar Harbor. When we compared the historic weather data from the top of Cadillac with the predicted weather, there were some days in which the weather was accurately predicted while others were not. This is seen in table 7, both 7/13/22 and 7/14/22 had predicted 4 degrees or less off from the historical weather; however, the difference between the model and the actual dwell time remained relatively consistent. This led us to believe that there was an additional limitation of the model.

Table 7: Chart of weather prediction and historical weather data

Date		Weather Underground Prediction	Weather Underground Cadillac Mountain Historical Data
7/11/22	Average Temperature	69ºF	64.6ºF
	Average Wind Speed	9.5 mph	15.1 mph
7/12/22	Average Temperature	66.5ºF	60.8ºF
	Average Wind Speed	16 mph	23 mph
7/13/22	Average Temperature	68.5ºF	71.4ºF
	Average Wind Speed	7.5 mph	9.6 mph
7/14/22	Average Temperature	64ºF	68ºF
	Average Wind Speed	5.5 mph	6.7 mph

This limitation is the weather inputs of the model. We found that cloud variables seemed to be very important to the dwell times of visitors. However, there are no inputs for cloud variables, such as cloud cover or cloud base. This further limits the model as we believe these are very significant factors.

4.3.3 ACCURACY:

The WPI project team's model was very accurate when using data remotely gathered by their team. The RSME listed in their report is 5.06 minutes (Kelly et al., 2022). After running the WPI project team model with our collected data, the RSME came out to be 22.5 minutes. This is over four times the error collected by the WPI project team and showed a large difference between their collected data and the data we directly observed.

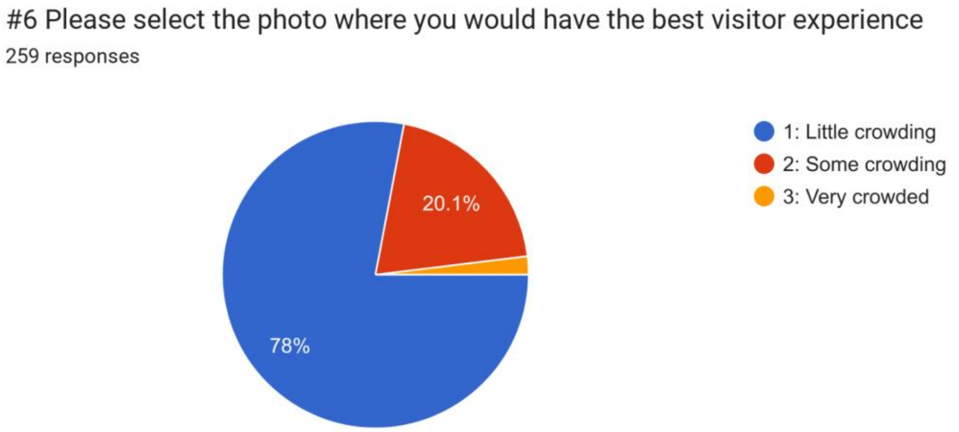
Within our own collected data, there seems to be some degree of error. On 6/27/22, there was a severe rainstorm throughout the entire time we were collecting data; however, in our weather data there were zero inches of reported rain for that day. Although not in any significant amount, we did occasionally miss the license plate of a car due to the license plate being illegible or visual interference from a visitor.

4.4.0 VISITOR DISTRIBUTION AND PARKING AFFECT VISITOR EXPERIENCE:

Since Cadillac Mountain's reservation system was still relatively new, examining evidence of the system's direct impact on visitor experience was important to determine standards of quality. To create a baseline so that all respondents could be compared on the same scale, three pictures of varying capacities were presented. The first (little crowding) showed approximately ten visitors, the second (some crowding) showed approximately twenty visitors, and the third (very crowded) showed approximately thirty visitors (Figure 4).

4.4.1 EXPERIENCED 'LITTLE CROWDING' BUT PREFERRED 'SOME CROWDING':

When showing visitors the three pictures of varying crowding levels (Figure 4), 46.9% of respondents stated that they experienced a situation most similar to the picture that represented 'little crowding' (Figure 14). However, only 2.7% of those who experienced 'little crowding' wished there had been crowding closer to the 'some crowding' scenario. To determine what this group of respondents felt 'little crowding' to be, we examined the pictures we took of the summit every half-hour. However, we could only examine one of these respondents as they were the only one who fell within the 10:00 am to 3:00 pm time period. While the picture at their reservation time related more closely to the 'some crowding' photo of twenty people, the visitors were clustered in large groups, as opposed to thinly scattered across the area. We concluded from this that crowding was related more closely to the distribution of visitors rather than the number.



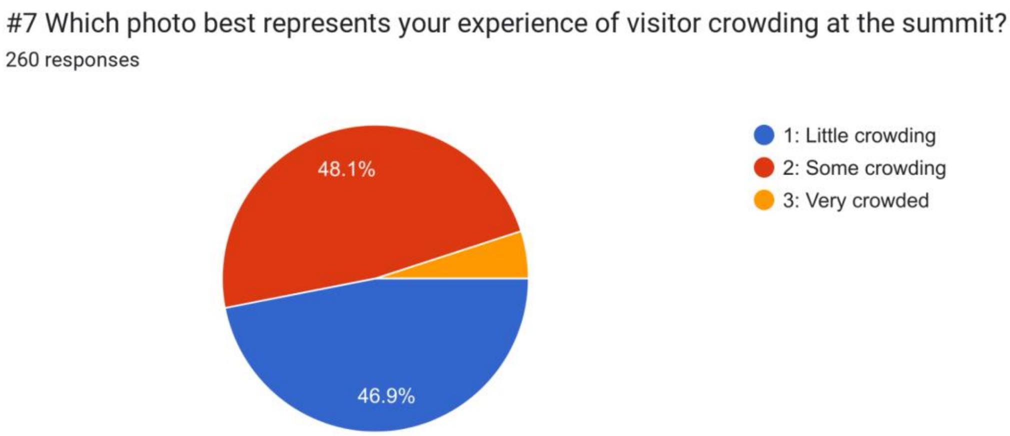


Figure 14: Visitor survey responses graphs

4.4.2 PARKING DIFFICULTIES IN RELATION TO CROWDING:

In terms of how visitors felt, finding a parking spot and the level of crowding they felt on the summit varied person-to-person. Out of 260 people, 1.6% of respondents found it to be extremely hard to find a parking spot and felt neutral about the level of crowding on the summit. On the other hand, 7.4% of respondents found it hard to find a parking spot. From this group of respondents, all the opinions ranged from neutral to very crowded on the summit except for one respondent who only felt a little crowded. As seen in figure 15, for the majority, the level of difficulty in finding a parking spot was the same level of crowding felt while they were on the summit. This correlation showed that parking and crowding are related to one another.

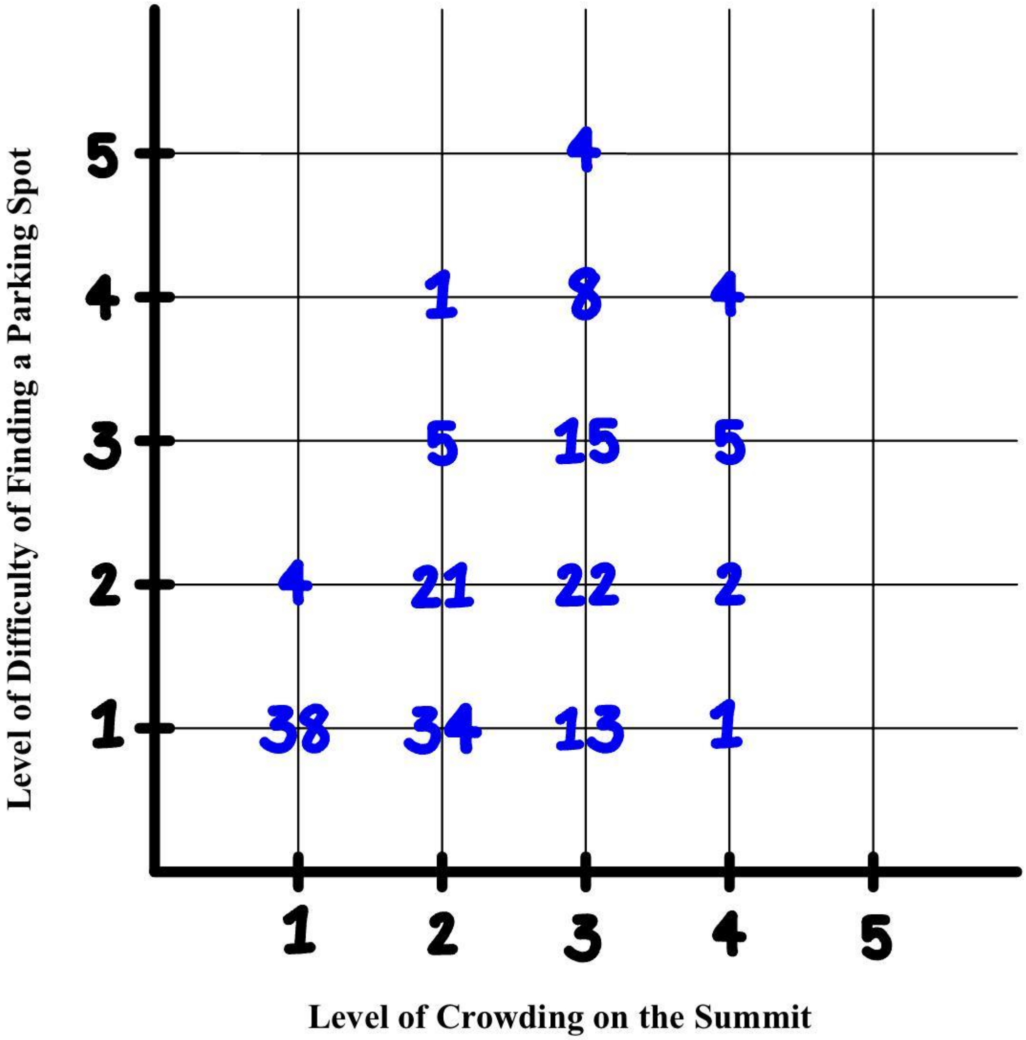


Figure 15: Graph of Level of Crowding vs. Difficulty of Finding a Parking Spot

4.4.3 CARRYING CAPACITY:

Calculated from the survey and excluding hikers and buses, on average, 3.65 people arrived at the summit per private vehicle (Figure 16). This was a 16% increase from the people per vehicle count found by the RSG (RSG, 2017). From our survey, only 9.7% of the respondents hiked, which led us to believe that the number of hikers did not cause the summit to reach maximum carrying capacity. However, we did not do extensive research on the number of hikers at the summit and therefore cannot draw significant conclusions.

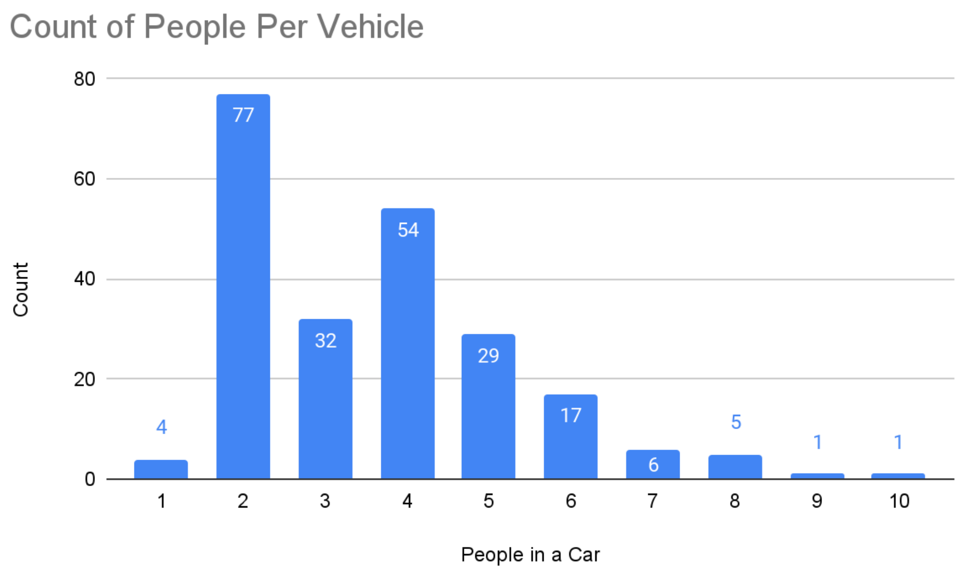


Figure 16: The count of people per vehicle

4.5.0 SUMMARY:

Compared to the RSG study and WPI project team, our dwell time is more closely related to vehicle dwell time rather than a visitor dwell time, which directly impacts the carrying capacity of the parking lot. Additionally, the WPI project team model was limited by big data.

The dwell time of vehicles fluctuates based on weather conditions. Compared to sunny conditions, rainy or foggy conditions resulted in lower average dwell times. After further examination, we determined that cloud base and cloud cover are important weather factors to consider in the WPI project team model.

Based on our findings, the current discrepancy with the WPI project team model arises from the limitation of weather forecasts for the summit of Cadillac. Weather Underground, the weather station used by the WPI project team, did not accurately predict the weather on Cadillac Mountain or included cloud base in its predictions. While the dwell time of vehicles fluctuates depending on weather, the WPI project team model was unable to represent this as the weather data used was not accurate.

We can conclude from the surveys that visitors felt the most congestion when there are people covering a larger range of areas, compared to larger clumps of visitors scarcely located across the summit. In addition, from the surveys, a correlation between the difficulty of parking and visitor crowding was found. The more difficult it was to find a parking spot, the more crowded people felt on the summit.

5.0.0 RECOMMENDATIONS:

Based on the findings of our research, we came up with four recommendations to improve the Cadillac Mountain Reservation System. To improve the accuracy of the WPI project team model, we recommend adding both cloud base and cloud cover as variables to the WPI model. Additionally, we recommend that the park continue to collect the dwell time of vehicles to create a larger data set for further development of the WPI model. To address under crowding and overcrowding of the summit, we recommend that the park adjust the number of reservations released to accommodate more or less vehicles. For our final recommendation, we recommend that future IQP teams observe visitor mobility and behavior patterns on the summit.

5.1.0 GATHER IMPROVED WEATHER PREDICTIONS :

An important step in the further development of the WPI model would be to include both cloud cover and cloud base. The lack of cloud data in the WPI model greatly limited its predictions. To improve the model there are two steps. The first step is to gather historical data for cloud cover and cloud base. This will allow these variables to be added to the model. The second step is to get cloud cover and cloud base predictions. We recommend getting these through Windy.com. Windy.com gives weather predictions for many different weather factors including cloud cover and cloud base. As of right now, these variables will need to be processed and inserted manually. Implementing these recommendations would allow the WPI model to give more accurate predictions.

5.2.0 COLLECT VEHICLE DWELL TIME:

We recommend that the park continue to track the dwell times of vehicles on the summit. By collecting data over a longer period of time, a more accurate dwell time can be calculated that better accounts for different weather conditions. While our study only included two days with precipitation, long-term monitoring of dwell times would allow for more accurate predictions. Although there is no current model for automated vehicle dwell time loggers, it does not seem impossible to use state-of-the-art AI computer vision platforms to be able to log license plates from commercial-grade traffic cameras. The Rekor Edge Pro is a commercial-grade camera from a computing company that offers an all-in-one solution. This camera captures the time, license plate, make, type, and color of the vehicle, and is available for $1500 with a $55 monthly subscription after the first year (*Rekor Edge Pro*, n.d.).

5.3.0 ADJUST THE NUMBER OF RESERVATIONS RELEASED:

To prevent under or overcrowding on the summit, we recommend that the park use the WPI project team model to adjust the number of reservations released 48 hours before each date. By including cloud base in the model's predictions and collecting more accurate dwell time data, the WPI model can be improved and used to predict future traffic on the summit. Depending on the model's predictions for a specific date, the park would have the ability to adjust the number of reservations released two days before. If the model predicted a large increase in volume and dwell time, the park would then be able to release fewer reservations. Similarly, the park could potentially release more reservations if the model predicted a significant decrease in volume and dwell time. As seen in figure 17, there is a drop in traffic volume around 6:00am and 6:00pm, and the park could potentially release additional reservations to allow more people to visit the summit.

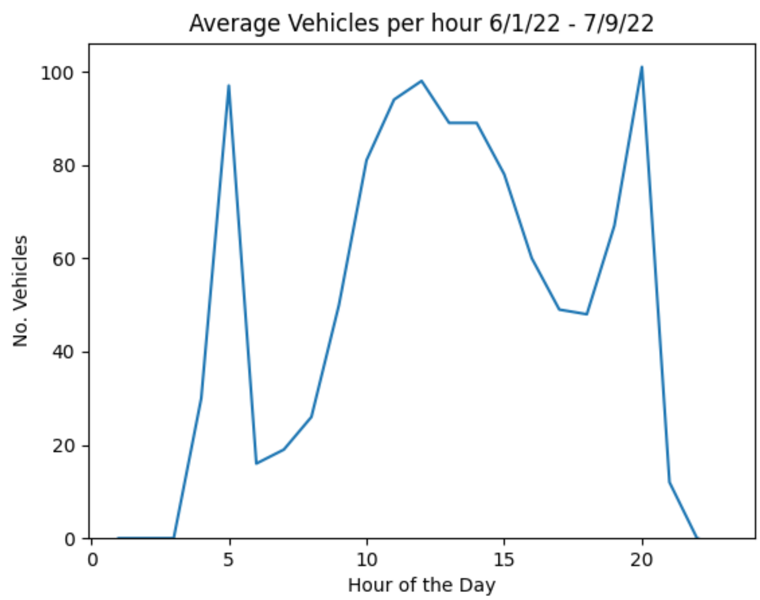


Figure 17: Average Vehicles per hour arriving on the summit (NPS, 2022)

5.4.0 OBSERVE VISITOR MOBILITY AND BEHAVIOR ON THE SUMMIT:

We recommend that future IQP projects focus on visitor mobility and behavior on the summit. While our project focused on the amount of time that vehicles spent on the summit, we were unable to observe how and where visitors spent their time. This information could then be used to establish a carrying capacity for the summit of Cadillac. In addition, it would help the park gauge what areas of the summit are the most popular and what areas could be optimized.

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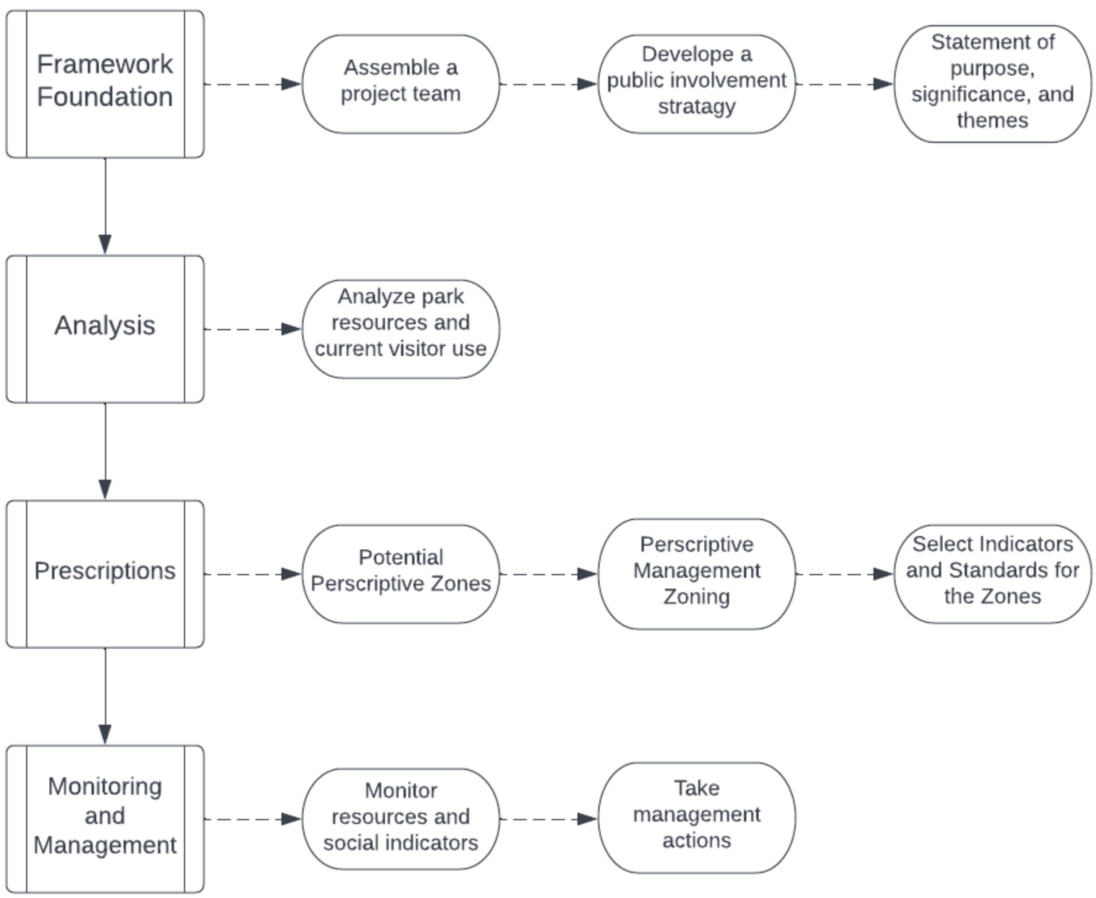
APPENDIX A: VISITOR EXPERIENCE AND RESOURCE PROTECTION:

The visitor experience and resource protection (VERP) plan was established by Robert E. Manning in his study of National Parks. The plan has four categories, each category containing at least one step. The first category, framework foundations, has three steps to be completed. Once those three steps are made, analysis of park resources and current visitor use should be done. This helps create prescriptions. Lastly, once all the steps and categories are in place, monitoring and managing the VERP plan is important.



APPENDIX B: PYTHON CODE OF DETERMINING DWELL TIMES

```
import pandas as pd
import numpy as np

# Must Have days in csv with the labels for the columns as "time_enter",
# "license_enter", "license_exit", "time_exit"
# Days Must start from 0 and increment by 1

days = ["6/23","6/24","6/27","6/28","6/29","7/1","7/2","7/3","7/6","7/7"]
half_hour_bins = []

# Creates 10 bins of dwell times in 30 minute increments for printing to show
# the breakdown of dwell time throughout the day
for i in range(len(days)):
  arr = []
  half_hour_bins.append(arr)

# Iterates through the days
for d in range(len(days)):
  # Loads a spreadsheet
  df = pd.read_csv(str(d) + ".csv")
  # Replaces NaN with 0
  df.replace(np.nan, 0)
  enter_df = df.iloc[:, :-2].dropna()
  exit_df = df.iloc[:, 2:].dropna()

  # Fancy Lambda statement to break the time into HH MM and then
  # convert to MM
  enter_df['time_enter'] = enter_df['time_enter'].str.split(':').apply(lambda
            +    x: int(x[0]) * 60 + int(x[1]))
  exit_df['time_exit'] = exit_df['time_exit'].str.split(':').apply(lambda x:
            +    int(x[0]) * 60 + int(x[1]))

  # Splits into 4 arrays
  ent_time = enter_df['time_enter'].values.tolist()
  ent_pl = enter_df['license_enter'].values.tolist()
  ext_time = exit_df['time_exit'].values.tolist()
  ext_pl = exit_df['license_exit'].values.tolist()

  # Creates an array to not double count visitors that come in and do loops
  # around the lot
  hasCounted = np.full(np.shape(ext_pl), False)
```

```
# List of Dwell times
dwell_time = []

# 10:00 in minutes
tme = 600
bin = 0
# Resets half hour iteration
curr_arr = half_hour_bins[bin]

# Iterates through entering cars
for i in range(len(ent_time)):
    entTime = ent_time[i]

    # Fancy code that moves the half hour block to the next
    if entTime > tme + 30:
        tme = tme + 30
        half_hour_bins[bin] = curr_arr
        bin = bin + 1
        curr_arr = half_hour_bins[bin]

    entLicense = ent_pl[i]
    ext = len(ext_time)
    # Iterates through exit plates from back to front
    for j in range(1,ext+1):
        k = ext - j
        extTime = ext_time[k]
        if extTime < entTime or hasCounted[k]:
            continue
        extLicense = ext_pl[k]
        if extLicense == entLicense:
            dwell = extTime - entTime
            dwell_time.append(dwell)
            curr_arr.append(dwell)
            hasCounted[k] = True

print(d)
print(sum(dwell_time) / len(dwell_time))
```