Preparing Acadia National Park for Modern Tourist Congestion

Exploring Impact and Feasibility of Reservation Systems and Gated Parking Solutions

IQP FB 1702

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

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Abstract

This project researched the feasibility of implementing a reservation system for the most congested portions of the day on Cadillac Mountain in Acadia National Park. The team investigated public opinion of reservations, observed and collected data for numerous metrics and constraints regarding implementing reservations and also designed the reservation process. The team used simulation modeling software and a cost-effectiveness analysis to recommend the required infrastructure for an optimal reservation system.

Acknowledgements

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Executive Summary

Acadia National Park is one of the smallest national parks in the United States, but also one of the most visited (National Park Service "IRMA Portal", 2016). Visitation to the park is only increasing; there was a 7% increase in visitors between 2015 and 2016, continuing a trend from the past decade. Cadillac Mountain is among the most popular locations in the park, and often has to close due to overcrowding at the summit (Trotter, 2015). The most crowded times are sunrise, sunset, and midday, as illustrated in Figure 1, a graph modeling the number of visitors at one time throughout the day on Cadillac Mountain. With only 158 parking spots between the summit lot and the nearby Blue Hill Overlook, many visitors park illegally or circle the lot several times to locate a space.

Figure 1: Peak Times on Cadillac Mountain, Shown in Visitors at One Time (RSG, 2016)

The mission of this project was to assist Acadia National Park in the management of seasonal overcrowding and tourist congestion through research on the impact and feasibility of an online reservation system with enforcement through a gated parking system. This was accomplished by obtaining visitor opinion on such a strategy, investigating how the system would be implemented by the park, and determining its cost and efficiency in handling traffic congestion on Cadillac Mountain.

The team's first method was to gather current public opinion on reservation systems for Cadillac Mountain. Visitors were surveyed at the Visitor Center and Cadillac Mountain summit area (see Appendix A for the complete survey). Surveys were conducted at midday, sunrise, and sunset on Cadillac Mountain. Based on the 104 surveys gathered, most visitors preferred an online reservation system (either online or through a mobile app) over other methods of making reservations. Additionally, the team found that most visitors preferred a two-hour reservation length, and were willing to pay an average of $5 for a reservation, but most responses ranged from not willing to pay to $20. There was no correlation between the number of times a visitor had been up the mountain and their opinion on a reservation.

The team observed how long vehicles parked on Cadillac Mountain during different times of the day to determine how long reservation time slots should be. The team found that during the midday, cars were parked for approximately half an hour. However, for sunrise and sunset, cars arrived at varying times before the sunrise and sunset, and generally remained parked until half an hour after sunrise and sunset. This led the team to develop a reservation system that would handle sunrise and sunset differently than midday.

Fee compliance on Cadillac Mountain was also observed. Fee compliance was defined as a car which was parked and had a pass clearly visible in their front windshield (Dziuban, Leahy, Sengstaken, & Whittle, 2016). Baseline values were taken at Sand Beach and Thunder Hole, as 100% compliancy is assumed because a park pass is necessary to reach these locations. The team found fee compliance on Cadillac Mountain to be lowest at sunrise (61.4%), as passes cannot be purchased from the Visitor Center at this time. Compliance peaked in the afternoon (84.6%) and decreased for sunset (75.7%). These percentages were used to determine how much benefit the park would receive if a reservation system ensured 100% fee compliance on Cadillac Mountain.

A simulation and modeling analysis was performed to determine the required number of lanes at the base of Cadillac Mountain for the cost-effectiveness analysis. The team gathered the necessary data for the simulation by observing queue times at the Park Loop Road entrance station and interarrival times at the base of Cadillac Mountain. Manned gates were found to be less efficient than automatic gates due to visitors exchanging extraneous information with the rangers. As a result of our simulations, one- and two-lane manned gates were not considered in the cost-effectiveness analysis.

To determine the optimal reservation and gating system for Acadia National Park's interests, the team performed a cost-effectiveness analysis. Two non-monetary factors considered in the cost-effectiveness analysis included environmental impact and visitor experience. Costs comprised of prices for reservation platforms, gating systems, and road expansion. Benefits included gains from reservation fees and increased fee compliance.

The most effective solution was determined to be a two-lane automatic gate system at the base of Cadillac Mountain (shown in Figure 2), with an independently run website to handle the reservation process. This solution is also the shortest worst-case and average queue times, leading to the highest visitor satisfaction rates, and has a moderate environmental impact, as the road would only need to be widened by one lane. An independently managed website would link park entry passes to the reservations made, ensuring those who make reservations will be fee compliant. While this solution is initially expensive, costing $292,500, if a $5 reservation fee were to be charged, sunrise reservations during a single peak month could make up to $69,400 and a peak month reserving both sunrise and sunset could make up to $121,800. Table 1 below illustrates a breakdown of the costs for this solution.

Figure 2: Recommended Solution Representation

Recommended Solution Cost-Effectiveness Analysis				
Category	**Item**	**Quantity**	**Price**	**Total**
Website	Independent Website	1	$30,000.00	$30,000.00
Gates	Automatic Gate	2	$100,000.00	$200,000.00
	Road	1	$62,500.00	$62,500.00
			Total Cost:	**$292,500.00**
			Total Benefit:	**$121,800.00**

Table 1: Recommended Solution Cost-Effectiveness Analysis

In order to test out the reservation system and allow visitors to grow accustomed to it, a phase-in plan would be required. In the proposed phase-in plan, sunrise would be implemented first using four-hour time blocks spanning the entirety of the peak time, with advance advertising to ensure as many visitors as possible learn about the reservation system before it begins. Sunrise was deemed the best peak time to test the reservation system due to the low number of visitors elsewhere in the park, creating less risk for the park as various aspects of the reservation system are tested and altered. After piloting the reservation system at sunrise, an outcome assessment should be performed by the park to evaluate whether the reservation system was effective. If it was deemed effective, the reservation system would be expanded to include sunset reservations, with the same four-hour block as the sunrise reservations.

The team believes it is feasible for Acadia National Park to implement a reservation system; however, there are many improvements to be investigated for the future, including ITS (Intelligent Transportation System) signs for increased knowledge of visitors, a centralized pass system to track which passes have reservations linked to them more effectively, and expanding reservations to midday on Cadillac Mountain and potentially throughout other areas of the park.

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Introduction

The National Park System of the United States is home to the most illustrious and grand scenery the nation has to offer. Families, researchers, and scientists from across the globe visit national parks each year to appreciate the natural wonders of the planet, and to ensure the health and sustainability of its species. All 405 parks within the National Park Service (NPS) work to preserve natural, cultural, and historical landscapes while "telling stories that reflect the great diversity of the nation" (National Park Service, "IRMA Portal," 2017). Over 330 million people visited national parks across the United States in 2016 to celebrate the centennial of the founding of the NPS (National Park Service, "IRMA Portal," 2016). With a 7% increase from the previous year (over 25 million visitors), national parks are becoming increasingly concerned with preserving the visitor experience with as little tourist congestion as possible.

This proves especially difficult for Acadia National Park on Mount Desert Island, Maine. Acadia National Park is the fifth smallest national park in the country, as well as being one of the top 10 most visited national parks (Acadia Centennial Task Force, 2017; National Park Service, "IRMA Portal," 2017). The volume of visitors increased by 18% last year with most visits occurring during the summer months (National Park Service, "IRMA Portal," 2017). Acadia National Park is looking for solutions to ensure the longevity of its high-quality experience for its many visitors.

With the increasing number of visitors to national parks, more people are able to appreciate the natural wonders the parks have to offer. However, the more people who arrive at the park, the more cars they bring with them, causing severe traffic concerns as well as wildlife damage from parking on the sides of the road. This also hastens the natural process of erosion, leading to damaged bridges and broken roads, and costing the park significant amounts of funding. During the summertime, when Acadia is busiest, pedestrians park anywhere they can and often without a pass. In his book, *Parks and People*, researcher Robert Manning postulates that an increased number of tourists causes additional wear on trails, as well as on the sides of roadways (Manning, 2009). At the moment, there is no way to ensure fee compliance for visitors who park along the sides of the roads. If tourists do not pay for a pass, they reduce the amount of funds contributing to the maintenance of the park.

The sheer volume of visitors at Acadia National Park, as well as congested traffic and limited parking availability, is hindering the visitor experience. VERP, or Visitor Experience and Resource Protection, is a standard used to determine the maximum amount of people that can be in the park without guests perceiving the park to be overcrowded (Manning, 2001). A VERP study in Acadia showed the maximum acceptable persons-per-viewscape (PPV) was around 14, but visitors preferred even fewer people being present (Manning, 2009). Popular destinations like Cadillac Mountain have significantly more people on the viewscape than intended, bringing their cars with them. Acadia has previously implemented temporary solutions to mitigate traffic congestion. Cadillac Mountain is closed down multiple times each year due to visitor traffic, and the Park Loop Road has delayed openings, creating “car-free openings” so the park can be enjoyed without the severe traffic congestion (Trotter 2014; 2015). However, private vehicles are, to some, an essential part of the Acadia experience, and cannot be completely removed (Manning, 2009).

Research was being conducted by Acadia National Park at the time of this project to determine the most feasible solution for reducing traffic congestion while retaining or improving the general visitor experience. This research relied heavily on input from the community and avid visitors of the park. Our project was to assist Acadia National Park in the management of seasonal overcrowding and tourist congestion by conducting research on the impact of an online reservation system for Cadillac Mountain enforced with a gated parking system. A reservation system for popular destinations like Cadillac Mountain, if implemented, could greatly improve visitor experience by providing limited access and restricting the people-per-viewscape. The reservation system also could have the opportunity to provide security for visitors as they are guaranteed access to the parking lot and a natural experience within Acadia National Park.

Background

In 1916, the National Park Service was established as a public, non-profit organization with a mission to protect the nation's natural environments and wonders (National Park Service, 2016). Today, over 400 areas throughout the United States belong to the National Park Service, with 59 of these areas specifically designated as national parks (National Park Service, 2016). Visitation to national parks continues to steadily increase with each year; a seven percent increase in 2016 and roughly 330 million visitors (National Park Service "IRMA Portal", 2016).

Traffic Congestion Concerns in Acadia National Park

Acadia National Park, located on Mount Desert Island, Maine, officially joined the National Park Service in 1919 (Acadia Centennial Task Force, 2016). Acadia is the only national park to arise solely from land donations from citizens; most of the land was donated by George B. Dorr (through the Hancock County Trustees of Public Reservations) and John D. Rockefeller (who also funded the construction of the carriage roads) (Acadia Centennial Task Force, 2017). To this day, the park continues to expand through land donations from citizens (Miller, 2016). Acadia is one of the top ten most visited national parks in the US, but also the fifth smallest, at only 49,057 acres (Acadia Centennial Task Force, 2017; National Park Service "IRMA Portal," 2017). For comparison, Table 2 outlines the top ten largest national parks (only official national parks were counted; other National Park Service properties were ignored). The largest, Wrangell-St. Elias National Park, received 79,047 visitors last year, averaging approximately 216 visitors per day if visitation rates were steady all year (National Park Service "IRMA Portal," 2017). The most popular of the top ten, Yosemite, had 4,257,177 visitors last year, averaging 11,632 visitors per day; this averages to 0.05 visitors per acre per day (National Park Service "IRMA Portal," 2017). Acadia's 3,303,393 visitors, or 9,026 visitors per day, average 0.18 visitors per acre (National Park Service "IRMA Portal," 2017). This density assumes an even distribution of visitors; it does not account for the fact that the number of visitors fluctuates throughout seasons. During peak seasons the density is even higher than this. It also assumes even distribution of visitors; most of the visitors tend to stay at the more popular tourist locations. Acadia is home to many popular locations for tourists, with the most popular locations in the park being Cadillac Mountain, Sand Beach, Thunder Hole, the Seawall area and Jordan Pond (Manning, 2009). The location of parking lots along Park Loop Road is outlined by Figure 3.

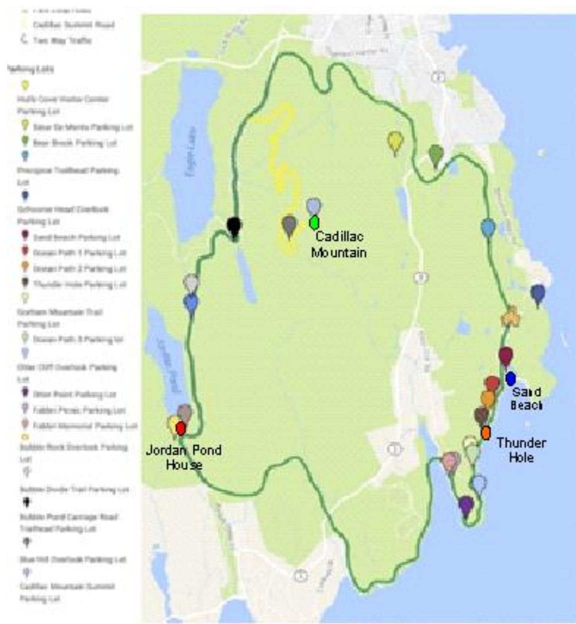

Figure 3: Location of Parking Lots and Popular Locations along Park Loop Road (Dziuban, Leahy, Sengstaken, & Whittle, 2016)

Park	Size (acres)	Recreational Visitors (2016)
1. Wrangell-St. Elias	**8,323,146.48**	**79,047**
2. Gates of the Arctic	**7,523,897.45**	**10,047**
3. Denali	**4,740,911.16**	**587,412**
4. Katmai	**3,674,529.33**	**37,818**
5. Death Valley	**3,373,063.14**	**1,296,283**
6. Glacier Bay	**3,223,383.43**	**520,171**
7. Lake Clark	**2,619,816.49**	**21,102**
8. Yellowstone	**2,219,790.71**	**4,257,177**
9. Kobuk Valley	**1,750,716.16**	**15,500**
10. Everglades	**1,400,539.30**	**930,907**

Table 2: Top 10 Largest National Parks (National Park Service "IRMA Portal," 2016)

Like the other national parks, Acadia is also seeing more visitors annually, an increase of 18% over the last year, with most visiting during the summer months (National Park Service "IRMA Portal," 2017). Figure 4 shows the increase in recreational visits to Acadia over the last four years. In 2016, most people visited the park in July (696,854 visitors), August (735,945) and September (570,434) (National Park Service “IRMA Portal,” 2017). There was a sharp increase in visitation between April and May and a sharp decrease between October and November (National Park Service “IRMA Portal,” 2017).

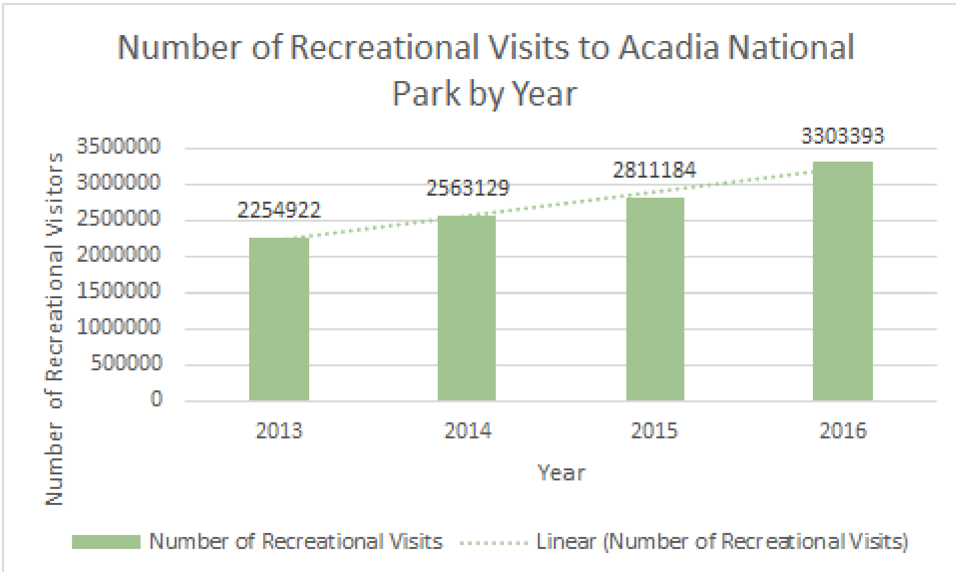

Figure 4: Increase in Recreational Visitors to Acadia National Park (National Park Service “IRMA Portal,” 2016)

Due to the increased presence of tourists, the park is becoming more difficult to maintain from an ecological standpoint. In *Parks and People*, Robert Manning postulates that an increased number of tourists causes additional wear to trails (Manning, 2009). Additional visitor traffic disturbs plant growth and when vegetation has a chance to re-emerge it is less diverse and consists of more resilient species. When more people go off designated paths, it causes unwanted erosion, uprooting plants along the sides of the path. Plant life naturally responds by being more resistant to the possibility of uprooting. This limits what species of plants are viable to grow in these locations, limiting the diversity of the plant life. Visitors walking off-trail also disturb the soil overall, leading to further erosion of the trails. In the 1990s, tourists were also introducing toxins into animal populations. A study in 1997 to 1999 concluded that mercury levels were increasing in tree swallows; high levels of mercury were causing many clutches of eggs to not develop (Longcore, Haines, & Halteman, 2007). The ecosystem is likely becoming even more damaged and deteriorating at a faster rate as tourist populations have steadily risen since the 1990s.

Crowding in Acadia National Park appears to have a large effect on the visitor experience. According to Robert Manning, who has extensively researched the visitor experience of Acadia National Park over the last few decades, VERP, or Visitor Experience and Resource Protection, is a standard used to determine the maximum amount of people that can be in the park without guests perceiving the park to be overcrowded (2001). A VERP study in Acadia showed the maximum acceptable persons-per-viewscape (PPV) was around 14, but visitors preferred even fewer people being present (Manning, 2009). Data from 1993-1997 showed that PPV levels at that time were approximately 5 PPV (Jacobi & Manning, 1997). Based on the increase in Acadia National Park visitation over the past decade this number has probably risen. Eighty percent of visitors reported a positive experience 90% of the time even during peak season (Jacobi & Manning, 1997). This percentage has probably decreased over the last decade as a consequence of increased visitor traffic.

The combination of Acadia's limited acreage and overwhelming visitation rate are damaging the environment and detracting from the grandeur of the park. Many factors influence the visitor experience on any given day in Acadia National Park. People who visit national parks tend to have some kind of intrinsic motivation for visiting. Usually, these motivations include wanting to get away from other people to escape the monotony of everyday life (Kim, Lee, & Klenosky, 2003). The push-pull theory, described by Kim, Lee and Klenosky in *The Influence of Push and Pull Factors at Korean National Parks* (2003) explains these motivations to travel to the park in the first place. Push factors are "factors that create a desire to travel," the more internal motivations (Kim, Lee, & Klenosky, 2003). Common push factors for many visitors include the concepts of escapism and a sense of adventure or accomplishment. Escapism is the desire to get away from the boredom or troubles of everyday life. This explains why people who visit national parks want to minimize the influence of other visitors; human presence takes away from the perception that they are outside of society. Adventure and accomplishment seeking motivates visitors to explore places they have not yet seen or draws them to less-visited areas. The push factors are generally used to decide when to visit the park, as they are self-motivating. Pull factors are related to the appeal of the destination itself, the more superficial or external motivating factors. These factors include the resources available and the appeal of recreational activities. These factors are used more to decide where the visitor wants to go within the park. Once in the park, position within the park affects how visitors perceive the influence of other humans. Visitors have a lower sensitivity to human impact near the outer boundaries of the park versus the innermost, most secluded of trails (Manning, 2009). While motivations seem to have the most influence over the lens visitors perceive their experience, location and other transient factors within the park also influence perception filters.

Potential Solutions to Traffic Congestion

Attempted Solutions to Tourist-Related Traffic Congestion

Lack of fee compliance compounds the issue of tourist-related traffic congestion by cutting into the funding the park should be using for self-sufficient operation and maintenance. Acadia National Park continues to be dramatically underfunded by the federal government; even a higher-than-expected $7.7 million budget in 2014 was not nearly enough (Trotter, 2014). As of 2015, Acadia National Park had 57.6 million dollars in backlog maintenance needed for the trails, paved roads and bridges which undergo the heaviest traffic by visitors (National Park Service “Acadia National Park,” 2015). Pass fees account for a significant amount of the Park maintenance budget; however, recent observations have shown that park visitors are not always compliant with these fees (Dziuban, Leahy, Sengstaken, & Whittle, 2016). In some areas of the park compliance is as low as 63% (Dziuban, Leahy, Sengstaken, & Whittle, 2016). One reason for this low compliance is that, “The park includes numerous uncontrolled entrances and exits and park roads are traveled by a large number of visitors, local residents, and others” (Manning, 2009, p.166). Furthermore, “90% of Park Loop Road is easily accessible without purchasing a pass … People can access the entirety of Park Loop Road when the fee station is unmanned” (Dziuban, Leahy, Sengstaken, & Whittle, 2016). Low fee compliance in the park limits the available funds for maintenance and is a challenging problem to address, given the size of the park and non-park related traffic passing through. Figure 5 shows a map of the park, with an indicator anywhere that a pass can be purchased. The only place passes are checked is the Sand Beach entrance station, indicated in yellow on the eastern side of the park.

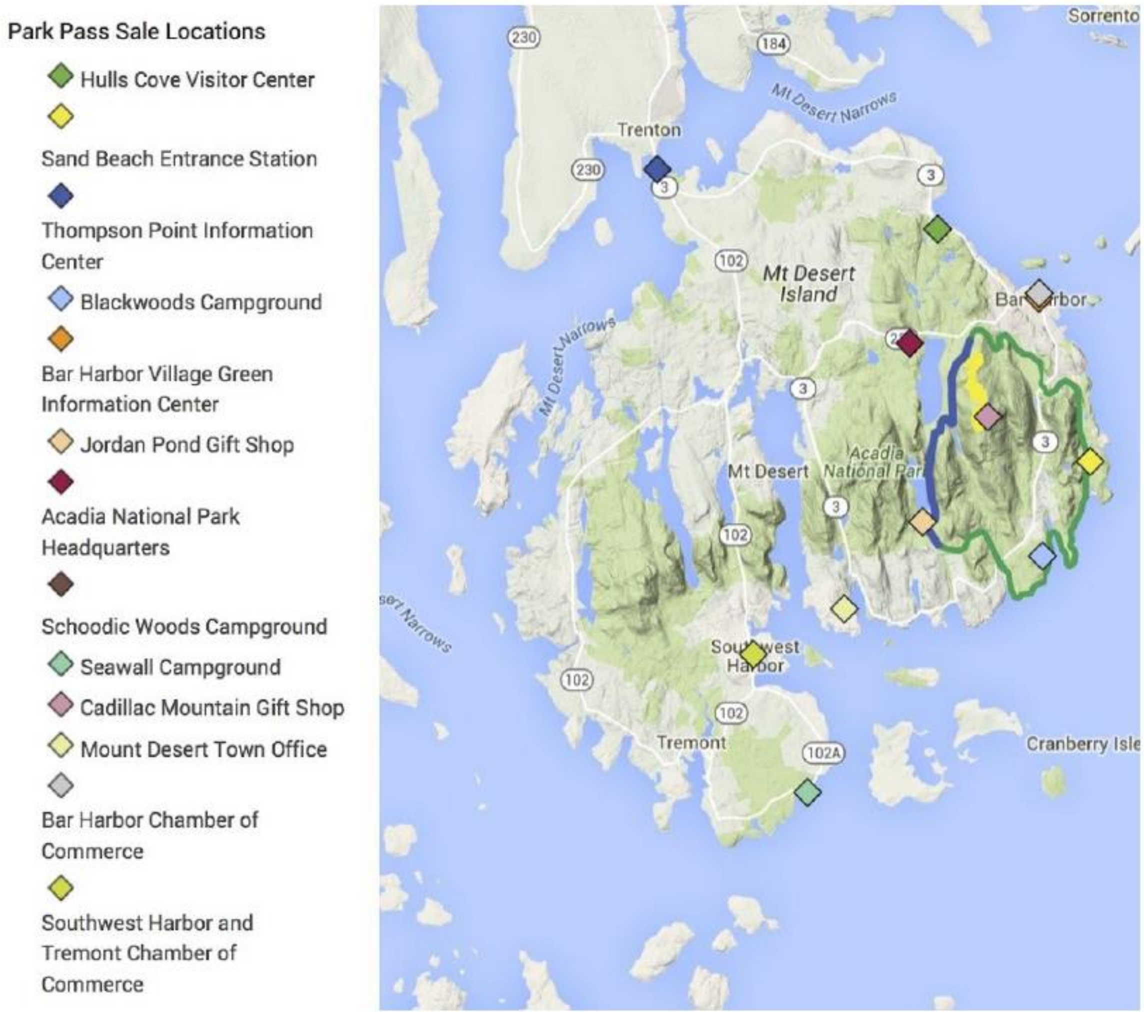

Figure 5: Pass Purchase Locations in the Park (Dziuban, Leahy, Sengstaken, & Whittle, 2016)

In the last two decades, several attempts have been made to lessen the tourist congestion problem in Acadia, or at least to alleviate its symptoms. In 1999, the park introduced the Island Explorer Bus, a free, voluntary way to get around the island without worrying about parking (Manning, 2009). In addition, several intelligent transportation technologies (ITS) were implemented to enhance the Island Explorer in the summer of 2003. Electronic signs in the visitor center were used to disseminate real-time travel information. These provided the next time of departure for the Island Explorer bus. Parking and traffic information was provided to visitors, including real-time parking conditions at Sand Beach and Jordan Pond House (Manning, 2009). Although each of these solutions reduced traffic to some extent, the overall impact on parking was not statistically significant (Manning, 2009). Manning writes that, "Many visitors stated that they weren't aware of the traffic information, or that it was inconvenient to access it online" (Manning 2009 p.209). Of those who used the bus service, many said they had already planned to take the bus, regardless of the additional traffic and parking information. These results suggest that ITS alone is not sufficient to eliminate parking problems, and that additional measures must be taken.

In 2016, two "Car Free days" were held, one on May 16th and one on September 26th (Kelly, 2016). These days resulted in temporary relief from traffic in the park, but cannot be relied upon for long periods of time. Cadillac Mountain is closed down multiple times each year due to visitor traffic, and the Park Loop Road has delayed openings, creating "car-free openings" so the park can be enjoyed without the severe traffic congestion (Trotter 2014; Trotter 2015).

Private vehicles are, for some, an essential part of the Acadia experience, and cannot be completely removed (Manning, 2009). Past attempts at reducing traffic and tourist congestion have had limited success, but more varied efforts are needed.

Low Tech Solutions to Traffic Congestion

Passive Management

Passive, or indirect, management of traffic flow is a low cost, albeit low impact, approach to reduce the problem in the park. Passive management denotes an attempt by the park staff to influence, but not directly control, the behavior of visitors to the park (Manning, 2009). For example, Manning suggests that, by manipulating the scenic features of the park, such as placing gravel on a trail, visitors can be effectively guided with a minimum amount of effort. For overcrowding in parking lots, Manning (2009) indicates that boulders can be strategically placed along the perimeter of a lot, to dissuade guests from overfilling the lot and to protect vegetation. This has the added benefit of maintaining the natural appearance of the park. If more passive techniques such as this can be designed and implemented, a reduction in traffic and congestion could be realized. These solutions are commonly used throughout parks everywhere, especially along the side of roads to prevent cars from parking on vegetation. This type of solution is only intended for a small scale. It can reduce congestion in and around one parking lot, but will most likely just push traffic to the next rather than eliminate it.

Manned Parking Solutions

Manned parking solutions require a person to manually collect money from each car, and are generally located at either the entrance or exit of a parking lot. However, this requires a continual cost of paying the employees, which in turn reduces income. Additionally, they slow down cars as each car must stop, open their window or door, hand the employee cash or a pass, and then either wait for the gate to raise or change to be handed back to them, depending on the particular implementation (Blythe, 1999). While this would ensure 100% fee compliance it would likely cause increased traffic congestion. This solution is the general approach to parking management at most state, private, and national parks with its extremely low setup cost making it a viable option at nearly every park.

Self-Pay Devices

Self-Pay devices, also referred to as Iron Rangers, are commonly used for state parks, campgrounds, and day use facilities (Iron Rangers, 2017; CNRCC, 2015). They are generally either based on the honor system or are enforced by officials ticketing non-compliant cars. Most of the time they include a tear-here tab to be placed in the windshield which contains a number that corresponds to the number in the payment envelop for officials to check. While these solutions cost less than manned solutions, they still require employees to retrieve the money from the Iron Rangers and to ticket the cars, if not based on the honor system. This is a common solution used at smaller parks and parking lots that are spread out over large distances where it is not economical to employee somebody to collect money.

Automated Solutions

Payment Stations

Payment stations are a way to automate the fee collection process, which removes the need for employees and increases the income from fees by reducing the overhead cost. There are many different ways to implement payment stations, however, they generally are capable of accepting cash, credit cards, or previously purchased passes (Dziuban, Leahy, Sengstaken, & Whittle, 2016). Payment stations could be a kiosk co-located in each parking lot and still be based on the honor or ticketing system, or be a gated system which requires payment at the entrance or exit of each parking lot to ensure 100% fee compliance. This approach reduces traffic congestion by eliminating the need for a manned station where cars have to stop and pay, causing a backup, and instead allow payment at each parking lot separately. These are commonly used in cities and parking garages where traffic backup is a serious problem and fee collection needs to be done at each parking lot, as stopping cars on a main road for payment is unviable.

E-Z Pass Solution

E-Z Pass solutions are high-scale solutions designed to handle extremely busy highways with either multiple payment lanes in a payment plaza, or overhead high-speed scanners designed to work without traffic slowing down. They are excellent at reducing traffic congestion with minimal to no effect, while maintaining a 100% fee compliance. However, they have extremely high setup cost, as Richard Somerville, a director for the Maine Turnpike and chairman for EZ-Pass, indicated it could cost anywhere between 8,500 USD to 17,500 USD per location (Dziuban, Leahy, Sengstaken, & Whittle, 2016).

RFID or Ticket Operated Gates

In 2016, a study on tourist usage patterns as a way to determine fee compliant and traffic congestion mitigation solutions was conducted at Acadia National Park (Dziuban, Leahy, Sengstaken, & Whittle, 2016). The study compared many different solutions and proposed that the best solution was a RFID (radio frequency identification tag) or ticket operated gate. They claimed it was a lower cost solution that still ensured 100% fee compliance, through the usage of RFID technology combined with a barcode reader for online printed tickets (Dziuban, Leahy, Sengstaken, & Whittle, 2016). These generally work by having gates at each entrance or exit to parking lots, specifically those where the initial setup cost warrants the 100% fee compliance. A RFID tag, come in two forms: an active one which is designed for long-range high-power communication but also requires a built-in expensive battery, and a passive one that is cheaper but only work for short distances (Bouet and Dos Santos 2008; Active RFID vs Passive RFID, 2017). The active ones generally cost about $7.80, while the passive ones cost between $0.74 and $1.25 (Dziuban, Leahy, Sengstaken, & Whittle, 2016). The latter is more economical and functional for gated parking lots, as the driver would simply have to swipe their pass or scan their barcode on the kiosk to raise the gate. Furthermore, tourists would have the ability to recharge their pass instead of buying a new one, by corresponding the ID on the card with an account (Dziuban, Leahy, Sengstaken, & Whittle, 2016). This is “the most efficient and cost-effective solution,” with minimal impact on traffic congestion and no overhead cost of employees, while still maintaining a 100% fee compliance rate (Dziuban, Leahy, Sengstaken, & Whittle, 2016). Like the automated payment stations, these are commonly used in cities where traffic backup is of utmost concern, yet implementing a larger E-Z pass solution is unviable.

Reservation Systems

For certain popular limited-access tours or permits, national parks often handle reservations through a lottery system. By using this random approach, national parks, “[provide] a fair distribution process and [ensure] equal access to the recreation opportunity” (“Recreation.gov”, 2014). Since lottery systems choose the winners in a random manner, it is guaranteed that the decisions are fair and that there is no pressure on applicants to stay up until the exact minute reservations open and rush to get a spot before other potential tourists, so those who are unable or unwilling to go to extreme lengths to get reservations can still do so and have an equal chance of attaining the reservation. To participate in a lottery, all applicants are required to have an account at the Recreation.gov website and pay a transaction fee. The exact amount varies by lottery, and is not refunded even to those who do not win the lottery. Through the Recreation.gov website, potential visitors apply to lotteries they desire either over the phone or online until the deadline passes, whereupon the entries are processed. All applicants are informed of whether or not they were chosen to participate in the lottery’s event, and winners can then confirm their slots in methods specific to each lottery location. While the lottery process does ensure fairness for all who want to participate, it also introduces a level of uncertainty. Potential visitors who want to reserve their place and immediately know that they do (or do not) have a guaranteed place for planning purposes are forced to wait until they are notified to continue planning their visiting experience.

Mammoth Cave National Park allows visitors to reserve spaces on tours in advance or claim any remaining slots in person. Reservations for tours can be made beginning six months before the tour up until the day before the tour itself (“Recreation.gov”, 2014). If there are any slots that have not been reserved on the day of the tour, visitors without reservations can fill those slots on a first-come, first-serve basis (“Cave Tours”, 2017). Reservations cannot be made on the day of the tour, since any physical visitors to the park are now able to claim the unreserved slots (“Recreation.gov”, 2014). However, while allowing for people who do not plan far in advance, this approach leaves those who do not reserve a space risking their chances to be able to go on any tours at all should the spaces have filled through reservations or earlier arrivals. It is possible to apply this approach to a parking lot or other non-tour situations, but the number of spaces remaining in the parking lot must be carefully monitored in order to prevent first-come visitors from being accepted when there is not enough space, either because the lot is already full or because all of the remaining spaces are reserved.

Unlike Mammoth Cave National Park, Haleakalā National Park, located in Hawai’i, requires a reservation in order to enter its Summit District to view the sunrise, and does not accept any visitors into that area if they do not have proof of their reservation ("Sunrise Reservation", 2017). This required reservation costs $1.50, so visitors must pay an additional fee to enter the park in addition to usual park entry costs. The reservation is only valid from 3am to 7am on the day of the reservation—after that time, no reservations are needed to enter the Summit District. Reservation tickets are available up to sixty days beforehand, and thirty additional spaces are made available two days before the reservation date ("Recreation.gov", 2014). Haleakalā National Park provides online reservations to observe the sunrise from the park through Recreation.gov. The park implemented this reservation system for viewing the sunrise due to excessive overcrowding during this time. While the four parking lots in the Summit District can only hold 150 cars, prior to the implementation of this reservation system, there would regularly be in excess of 300 cars in the lots and along the sides of the road, harming the natural resources of the national park and obstructing emergency vehicles ("Sunrise Viewing", 2016). Even if there are unfilled places, those without reservations are prevented from driving their cars into the Summit District between 3am and 7am. However, anyone without a reservation is still able to enter the Summit District by bike or on foot ("Sunrise Reservation", 2017). The reservation system allows Haleakalā National Park to forcibly limit the number of cars allowed into the park at this highly congested time, creating a situation that is safer and more enjoyable. While this approach does ensure that parking lots are not exceeded and crowds are manageable, if there are slots in any given day that are not filled by reservations, they are wasted, as no first-come first-serve option is supported.

Everglades National Park employs a system involving passes to the park that can be purchased and shown on potential visitors' phones using Smart Destinations, a company that provides online passes for select locations. When tourists purchase passes through Smart Destinations, they receive an email with their pass in it ("Smart Destinations", 2017). That pass can be printed out by the visitor to be presented at the park, or it can be displayed directly on the phone, although this requires the visitor to have the Go City Card App on his or her phone. This pass is accepted at the Homestead and Shark Valley entrances, and allows the pass holder and the passengers of the vehicle or family members (when not traveling by car) into the park ("Fees – Everglades National Park", 2017). By using the phone as a medium to purchase and display passes, visitors enjoy increased convenience by having their passes on their person at all times through their phones, and makes it less likely that visitors will forget the necessary proof that they have a reservation or pass. These systems are summarized in Table 3.

System	Pros	Cons
Lottery System	-Fair to all participants	-Chancy -Participants must wait to know if they won a slot -Requires an account and transaction fee
Mammoth Cave Tour Reservation	-Allows unreserved spots to be filled on a first-come, first-served basis -Those who reserve know their place is secure	-Reservations not allowed on the day of the tour -May seem unfair to those who arrive without a reservation before those with reservations
Haleakalā Sunrise Reservation	-Those who reserve know their place is secure -Additional reservation slots are opened two days before the reservation date	-Unreserved spaces are wasted -Additional fees in addition to required fees to enter the park
Everglades Phone App	-Allows visitors to show their pass without printing out documents -Convenience	-Requires the phone app to get the most use -Phones must have reception to work properly

Table 3: Summary of Reservation Systems

Summary

Acadia National Park suffers from heavy tourist congestion every year. Potential solutions to this congestion include the implementation of a reservation system to allocate parking in advance and limit the number of cars allowed into a parking lot based on the reservation, as well as gated parking lots with a low-tech or automated solution. This information informed the project by providing models for potential gated parking lots and reservation systems, which were applied to the unique situations in Acadia National Park.

Methodology

The mission of this project was to assist Acadia National Park in the management of seasonal overcrowding and tourist congestion through research on the impact and feasibility of an online reservation system with enforcement through a gated parking system. To accomplish this mission we determined the answers to the following questions, as outlined in Figure 6:

- What is the public opinion on strategies to mitigate parking lot congestion? What solutions do visitors and staff believe would be the most effective?
- What effect would a gated parking system or reservation system have on the visitor experience? In what ways will the experience improve and in what ways will these strategies detract from the experience?
- How efficient would a gated parking system be for Cadillac Mountain? How much would the system cost, and would the infrastructure improvements be worth the initial and maintenance costs?
- How efficient would a reservation system be for Cadillac Mountain? How much would a system cost, and will the advantages to visitors be worth the initial or maintenance costs?

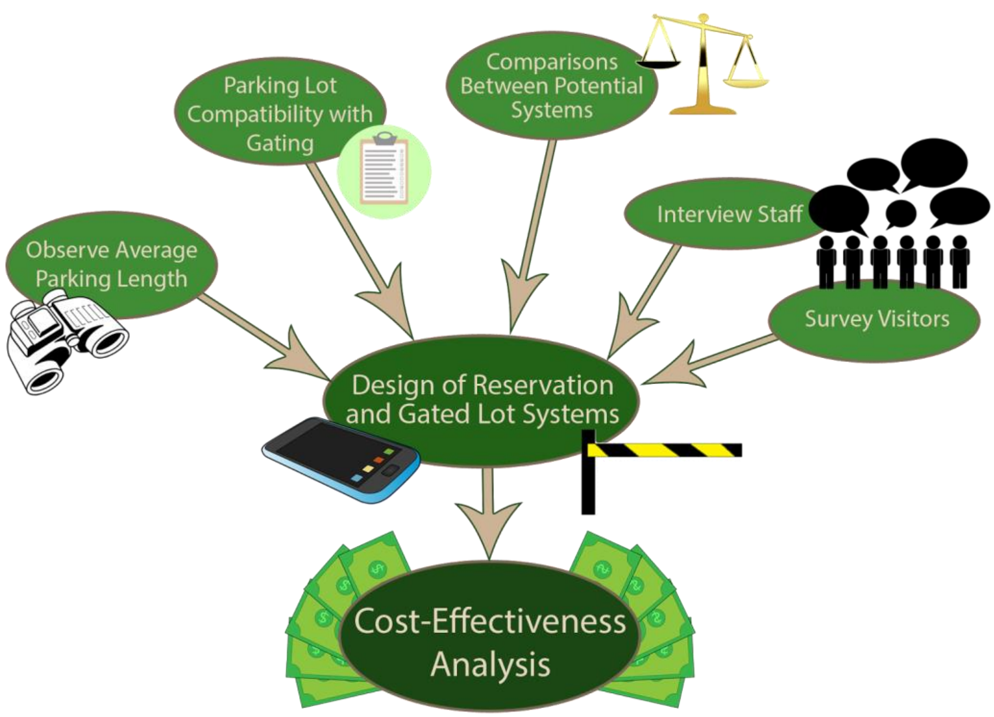

Figure 6: Project Overview

Survey Visitors

We administered a survey to visitors of the park at the Visitor Center and Cadillac Mountain. The surveys helped us determine public opinion on the feasibility of implementing gated parking solutions in combination with a reservation system at Acadia National Park, as well as such a solution's impact on the visitor experience, thus answering the following objective questions:

- What effect would a reservation system have on the visitor experience?
- How does visitation rate affect visitor opinion on reservations?
- How much would visitors be willing to pay for a reservation?
- What method would visitors prefer to use to reserve parking on Cadillac Mountain?

Our goal when conducting these surveys was to determine how likely the average visitor was to use a reservation system (see Appendix A for the survey questions with consent statement). We provided a verbal explanation of the purpose of our survey. A strength of surveying was that we were able to collect many responses quickly and anonymously. These surveys consumed team resources, and it sometimes proved difficult to find visitors who were willing to take the time to give us useful information. We attempted to prevent bias by phrasing the questions in a way which did not suggest the same answer as our assumptions, and by asking a variety of visitors rather than only speaking to one demographic.

These surveys were conducted at the convenience of passing visitors in the park at the Visitor Center and Cadillac Mountain Summit, at varying times on both weekends and weekdays. Specifically, we conducted surveys from noon until two at both the Visitor Center and Cadillac Mountain, a peak time of day in the park. We administered additional surveys at sunrise and sunset on Cadillac Mountain. This created enough variability in our data to draw conclusions about the population that visits the park. A convenience sample of 26 individuals was surveyed across each site and time for a total of 104 surveys. Twenty-six surveys at each location was an adequate number, as it exceeded the average number of data points, twelve, needed for saturation of data in a given population (Guest, Bunce, & Johnson, 2006).

We tabulated the survey takers' opinions and views, along with any comments they added around the questions that indicated an especially strong opinion, in an Excel spreadsheet. Our results allowed us to discover any trends regarding visitor opinion and reservation systems, such as perceived necessity and desirability, and if that information changed based on the location of the survey location and time of day. We used this data to support our final recommendation.

Interview Staff

We interviewed staff that consistently interact with visitors of the park to obtain their opinion on the necessity of the potential solutions as well as any insight into the impacts of such systems. This included park rangers, tour guides and management. The questions this method answered were:

- What solutions do visitors and staff believe would be the most effective?
- How would the systems affect Acadia National Park and the staff working there, both in terms of environmental impact and fee compliance?

After arriving in Bar Harbor we emailed the staff with our request to interview. We arranged interviews with staff members who were willing to participate and who we felt had enough background knowledge to provide information. We also asked park staff whether or not technological solutions to parking congestion would improve the park experience and make their jobs easier without having a severe environmental impact (see Appendix B for a full list of questions and written consent form).

These interviews were conducted at the convenience of the staff at various locations around the park. By collecting information from a variety of staff members in different roles and with different levels of experience, we could accurately represent the ideas of the staff as a population. We aimed for a convenience sample of 26 staff members with as much of an even distribution across roles as possible in order to reach appropriate saturation of the population (Guest, Bunce, & Johnson, 2006). We recorded basic demographic information about the staff members such as age, gender, and role within the park.

Our goal in conducting these interviews was to determine staff opinion on the visitor experience, fee compliance and environmental impact, as well as how feasible the staff believed potential solutions may be. We used the results of our interviews to discover if there are any aspects of the potential solutions that are particularly important to the staff, which we considered as we designed solutions.

Observe Average Parking Length

Our first step in determining the effectiveness of a reservation system was to find the average time cars spent in the parking lots on Cadillac Mountain. This helped us to decide upon the length of a reservation for our proposed reservation system if it were to be implemented on Cadillac Mountain. By using this information to develop an appropriate length of time for our potential reservation system, this method provided data used to answer the following question:

- How efficient would a reservation system be for Cadillac Mountain?

To do this, we used the natural observation method to watch cars in the Cadillac Summit and Blue Hill Overlook parking lots and recorded how long each one remained. This method was chosen due to its simplicity and accuracy in determining how long cars remain in parking lots. This was a low-tech solution that was easy for our team to implement. However, this method did rely on the team not becoming distracted or leaving for extended periods of time, as we had to keep watching the cars at all times for accurate arrival and departure times. We minimized this by staying in groups of two or three members, so multiple people were tracking each car and others could leave if they needed to. This method was time-consuming, but it was a simple and accurate way to obtain the data we needed for our reservation system.

Visitors who parked at the parking lots on Cadillac Mountain (both the summit lot and Blue Hill Overlook) were the target population of this method. We sampled a portion of the parking lot on days during both peak and nonpeak season, recording information consisting of cars' arrival times, departure times, and brief descriptions of the cars, used only for the purposes of identification by the member recording the information (the full form is located in Appendix C). We observed the parking lot in two-hour intervals, spending one day looking at peak times and the next day at nonpeak times. An exception to the two-hour interval was made for sunrise and sunset, as the parking lots rapidly emptied within half an hour of the sun rising or setting.

Potential ethical considerations for our team regarded the information we collected relating to the privacy of the visitors. We did not initiate any interactions with the visitors. We did not record or use any personal information about the visitors that we observed beyond what we needed to identify the car when we observed the length of time it remained in the parking lot.

The data we obtained was analyzed by finding the total time spent by each car in the parking lot (departure time minus arrival time). By taking the average time spent by the cars in the parking lot, we determined how long a typical person leaves a car in the parking lot, giving us a basis for a reasonable proposed length of a reservation system.

Observe Fee Compliance

In order to better perform a cost-effectiveness analysis, we had to determine how many cars were fee compliant. This would allow us to determine how much money the park would potentially make from installing a gate or reservation system which ensured fee compliance. Cars were considered fee compliant if they exhibited a valid and visible park pass (Dziuban, Leahy, Sengstaken, & Whittle, 2016). Motorcycles were excluded because they weren't required to display a pass and represented a small portion of the total population. We found fee compliance statistics at Cadillac Mountain, Sand Beach, Thunder Hole, and Jordan Pond parking lots. This information was used to confirm the statistics on fee compliance gathered in a study by a Worcester Polytechnic Institute team in 2016 and helped to answer the following question:

- How efficient would a reservation system be for Cadillac Mountain?

Before we gathered fee compliance data at Cadillac Mountain, we first observed fee compliance at Sand Beach and Thunder Hole, the two most popular visitor attractions which were also along the only stretch of Park Loop Road requiring a pass to enter. By determining the fee compliance at locations that should be 100% compliant, we determined an error which could be applied to the compliance data on Cadillac Mountain, which does not require a pass to access by car. We observed fee compliance at both peak and nonpeak times of day. To collect a variety of data from both peak and nonpeak times, we observed Cadillac Mountain Summit parking during the same times we calculated average parking length: sunrise, 8-10am, 11am-1pm, 3-5pm, and sunset. For the other locations, we observed fee compliance at the times of 10-11am and 12:30-1:30pm, in accordance with the previous Worcester Polytechnic Institute Study (Dziuban, Leahy, Sengstaken, & Whittle, 2016).

We determined fee compliance using the natural observation method. We combined this method with observing parking lengths. When we arrived at the parking lot, we checked every parked car, regardless of whether it was parked legally or not, for a prominently displayed and valid park pass. On Cadillac Mountain, we then observed cars as they arrived and left for our average parking length method. Near the end of the time slot, group members not waiting on cars to leave circled the parking lot once more to check a second group of cars for fee compliance. Although we could have found fee compliance of cars watched while determining average parking length, we opted to remain as unobtrusive as possible during that method and not potentially unnerve visitors by investigating their car as soon as they parked and moved away from it.

The average fee compliance of each location was gathered by dividing the total number of cars by the number of fee compliant cars. This information was stored in an Excel spreadsheet and tabulated into bar charts. The percentage of non-compliant cars at Thunder Hole and Sand Beach was applied to the Cadillac Mountain data to obtain an error range for the true fee compliance to account for cars that had a pass but forgot to display it. These percentages allowed us to determine how much money the park could potentially make if it were to implement a gate or reservation system that not only restricted traffic up Cadillac Mountain but also required visitors to purchase a park pass.

Assess Parking Lot Compatibility for Gates

To answer the question of how efficient and feasible a gated lot system would be in the park, we first assessed which parking lots were physically suitable to become gated lots. A parking lot was deemed suitable for a gate if it had a separate entrance and exit for cars. In addition, it ideally had “sufficient obstruction” around these entrances to prevent cars from simply driving around the gate. If a lot is surrounded by a flat, grassy area, cars could drive over the grass and avoid the gates. Similarly, even if a parking lot was surrounded by trees or boulders, if it was a pull-off without a clearly defined entrance and exit, it would be impossible to add in gates. This method provided information to answer the following question:

- How efficient would a gated parking system be for each lot in Acadia National Park? More specifically, are the parking lots we are looking to turn into gated lots shaped to actually support gates?

We completed this objective by using a natural observation method, visiting parking lots around Acadia to determine their suitability to be converted into a gated lot. This method was appropriate because it provided a simple and cost-effective way for us to find parking lots that could conceivably become gated lots. An alternative to this approach would have been to investigate the lots remotely via Google Maps, Google Earth, or other similar technology. However, this approach would have limited us to seeing only what the images provided, and top-down images may appear deceiving, such as tree foliage above an entrance to a parking lot, making it appear as if that entrance did not exist. By seeing each lot in person, we were able to obtain all of the information we required without being restricted by inconvenient image angles.

The targets for this method were the parking lots along Park Loop Road, including the parking lots of the four major tourist attractions on Park Loop Road: Jordan Pond, Cadillac Mountain, Sand Beach, and Thunder Hole. This totaled eighteen lots, as there were fourteen lots not associated with a major attraction. To collect the data used to determine if a parking lot was deemed suitable for becoming a gated lot, we used a form (located in Appendix D) which contained all of the relevant aspects of the parking lot, including location, number of entries and exits, if it was surrounded by natural obstacles, and size (total number of parking spaces in the lot). Once we collected the data for each parking lot, we evaluated the parking lots to determine if they were viable candidates to become gated lots as they were, if they needed adjustments, or if they were completely unfeasible. Adjustments could include adding boulders or other natural obstacles around the parking lot's perimeter to prevent cars from avoiding the gate (Manning, 2009). Although we primarily focused upon designing a gate and reservation system for Cadillac Mountain, this data was still collected to determine if gated parking could potentially be implemented throughout the park in the future.

Comparisons to other Systems

Comparison of Various Parking and Reservation Solutions

To recommend or prototype a potential parking or reservation system and evaluate the efficiency such a system would operate at, we first needed to know what solutions would be most effective in the context of Acadia National Park's needs. To do this, we researched various possible solutions. This allowed us to better understand the technology that we would be suggesting they implement. The questions this strategy answered are:

- How much would it cost to implement each proposed strategy?
- How efficient would each system be?
- How effective would each system be for each proposed location?

Gates and Other Parking Management Strategies

To get a better understanding of what would work best for the park, we compared multiple possible parking solutions. Among these solutions were those outlined in the background: passive management, manned parking lots, self-pay devices, payment stations, E-Z Pass and RFID/ticket operated gates. We also compared these solutions to the possibility of a mandatory busing system for at least part of the park.

To make these comparisons, we created a data matrix. A data matrix is an m x n array of quantitative data where m is the number of items being compared (the number of possible transportation solutions, in this case) and n is the number of variables used to compare them (Powers & Knapp, 2010). Quantitative information we used included implementation costs and scaled ratings given in interviews from the public.

We also compared the solutions qualitatively. Qualitative data analyzed traffic management systems from other parks - relative impact, ease of use, feasibility and timeframe for implementation, and how new and revolutionary the technology is. This data came from research of other parks' and more commercial systems. Appendix E shows the matrix that was used to compare different gated parking technologies.

Reservation Systems

This process worked similarly to that described above; different ways of formatting a reservation system were compared using multiple parameters. We compared the potential effectiveness of reservations of different lengths based on the data we collected earlier. We also compared different platforms for the system, such as Recreation.gov, a new section for the Friends of Acadia site or a newly developed website or app. We also compared different ways of enforcing reservations: using manned or automated gates or enforcing the displaying of passes with a rigid ticketing policy. Appendices F through H show matrices that were used to compare reservation system formats and make the best possible recommendations.

Design of Reservation System

Designing a reservation system requires both knowledge in website design and successful system models from other organizations. The system must be intuitive, accessible, and easy to maintain. A case study of other reservation systems provided website/app features that users want, as well as identifying potentially complicated structures. These features range from the basic functionality of the system, like user accounts for user authentication, to possible conveniences such as Facebook integration and PayPal support. Although very few national parks currently use reservation systems, the general reservation model has been successfully implemented in hotels, air travel, campgrounds, and even restaurants. The cost and the effectiveness of a reservation system for Acadia National Park could not be estimated without some idea of the features it would offer, and its physical implementation. Identifying specific explicit and implicit requirements for the proposed system was therefore integral to the overall cost-effectiveness analysis.

A case study of 5-10 different reservation systems, for a wide range of applications, provided a good background in the necessary features. Some amount of technical research was required to determine how to implement those features, and to estimate the cost of implementation and maintenance. By studying different reservation websites, we identified the features and functionality required by a similar system for Acadia. Ultimately, a prototype system optimized for use in the park was developed, with practical considerations such as accessibility kept in mind. The conducted research, in turn, provided a working estimate of the costs and impact of the prototype system.

Design of Gated Lots

Several different types of technology have already been adapted to automate gated parking systems. In order to design a potential gated parking solution for Acadia National Park, the relative advantages of each type had to be understood. To accomplish this goal, a case study was used. A case study with a wide sampling range gave a good cross-section of the different technologies used in gated parking systems. RFID and image detection systems were the main focus, but other options were also explored. A case study also gave us an idea of the associated costs with each type of solution, and the overall effectiveness.

For each identified solution, a minimum of three examples from any large-scale application gave a good indication of the expected costs and benefits, as well as the variance associated with each particular system. This data was primarily obtained online, and analyzed by the project team. As the only goal of the case study was to compare different technological solutions in terms of cost and effect on congestion, the environmental impact was ignored. In most cases, however, the technology used will have little, if any, environmental impact, so this concern is minor.

It should also be noted that Acadia National Park consists of several smaller parking lots, as opposed to one large one. Some systems can be easily adapted to this without a large price increase, while others may become prohibitively expensive. This “Scalability factor” was kept in mind during the case study, despite our focus on the Cadillac Mountain parking lots.

The data was used to decide which technology was most suitable for an automated gated parking system in Acadia National Park. Then, the collected information on cost was used to provide a preliminary estimate. Sketches were prepared based on other implementations of the same system.

Cost-Effectiveness Analysis

In order to assess the capital requirements and effects of the gated parking lots and online reservation systems, a cost-effectiveness analysis was performed. A cost-effectiveness analysis is a technique which compares the relative costs to the effects of a course of action (“BetterEvaluation: Cost Effectiveness Analysis”, 2004). A cost-benefit analysis is a systematic process, defined for comparing the costs to the benefits of a project (“BetterEvaluation: Cost Benefit Analysis”, 2014). The most common use for a cost-effectiveness analysis, rather than a cost-benefit analysis, is for situations where the effects cannot be easily quantified, such as impacts on the visitor experience and the environment, making this analysis ideal for our investigation. However, the two analyses are similar in kind and most of the steps overlap. We combined the steps to perform a basic cost-effectiveness analysis, as defined by Piroska Bullen from tools4dev, with those from the Pennsylvania Department of Environmental Protection's simple benefit/cost analysis tool as follows (Bullen, 2014; Pennsylvania Department of Environmental Protection):

1. List which improvements and outcomes will be used. These improvements were determined from the earlier methods of interviewing the visitors and staff, observing the time spent in each location, and assessing their compatibility. The outcomes were the results of the improvements. The goal of this step was to get a list of every factor that is involved in the cost-effectiveness analysis to be able to measure the difference of each outcome.

2. Identify all foreseeable monetary, personal, production, environmental, customer, and product costs and effects. This was directly taken from the interviews, observations, and comparisons to other systems. The goal of this was to create a set of influences to rank later.

3. Measure and rank costs and effects. The costs can be ranked from 1 to 3 or by using a common unit such as the USD, and converting all monetary costs into that unit (San José State University). The effects were measured using the simple cost-effectiveness analysis, by comparing the results of the data from the previous method with each other (Bullen, 2014). This way, the monetary benefits such as costs of hiring employees, startup costs, and maintenance costs could be compared, and non-monetary benefits such as visitor experience and environmental impacts could be separately compared with each other. With the cost-effectiveness analysis, non-monetary benefits can only be compared with the same type of benefits (Bullen, 2014).

4. Calculate cost-effectiveness ratio. For monetary influences, the ratio was determined by dividing the costs into the benefits, resulting in a ratio that, if greater than one, contained benefits greater than the costs; if equal to one, then the benefits were equal to costs; and if less than one, benefits were less than the costs. Alternatively, for non-monetary influences, the ratio was calculated by dividing the costs by the outcomes, to determine the cost per outcome. The results of the procedure gave us a ratio that was used to determine the effectiveness of the influences' outcomes.

5. Order the improvements by the calculated cost-effectiveness ratio. Creating an ordered list ranking the improvements from best to worst and graphing them for a visual representation allowed us to easily compare the effects and evaluate our proposed solutions.
The form for this process can be found in Appendix I.

Summary

To propose and assess reservation and gated parking solutions to Acadia National Park's traffic congestion problem, we gathered data, including visitor and staff opinion, length of parking reservations, and suitability of parking lots to become gated lots. By applying this information in comparisons to other systems and developing our proposed solutions, we determined which solutions were the most effective and feasible by applying a cost-effectiveness analysis to these solutions. Through this analysis, we accomplished our mission of assessing efficiency and capital requirements, evaluating visitor experience, and determining public opinion, which ultimately resulted in our final recommended solutions for Acadia National Park.

Results

Due to the park's recommendation, the team focused on designing a reservation system for Cadillac Mountain. Upon arrival to the park, the team was given access to a report by RSG (2016) which studied traffic flow up Cadillac Mountain, along with the volume of visitors to the mountain. This report concluded that Cadillac Mountain was "visually overcrowded" 80% of the time between 8AM and 5PM and "physically crowded 38% of the time during that same time frame. Visual crowding occurs when there are eight people per viewscape (people within one's visual field at any given moment) and physical crowding occurs when there are fifteen people per viewscape (RSG, 2016; Manning, 2009).

After examining eighteen separate parking lots, we have concluded that installing gates along Park Loop Road would cause more traffic congestion and would not add any value to the overall flow of the park. Most parking options along Park Loop Road are pull-offs without separate entrances and exits. These parking lots would not be feasible for gated solutions, as there would be no logical position to place a gate. Most of the lots that did have separate entrances and exits could hold fewer than twenty cars and any increase in efficiency from adding a gate would be minimized from the small size of the lot. Gated parking along the one-way section of Ocean Drive is unnecessary because visitors have the option to park in the right-hand lane in most areas, and would not increase fee compliance since park visitors are required to have a pass to enter that portion of the park.

Surveys and Interviews

For a comprehensive listing of all visitor survey answers, see Appendix J.

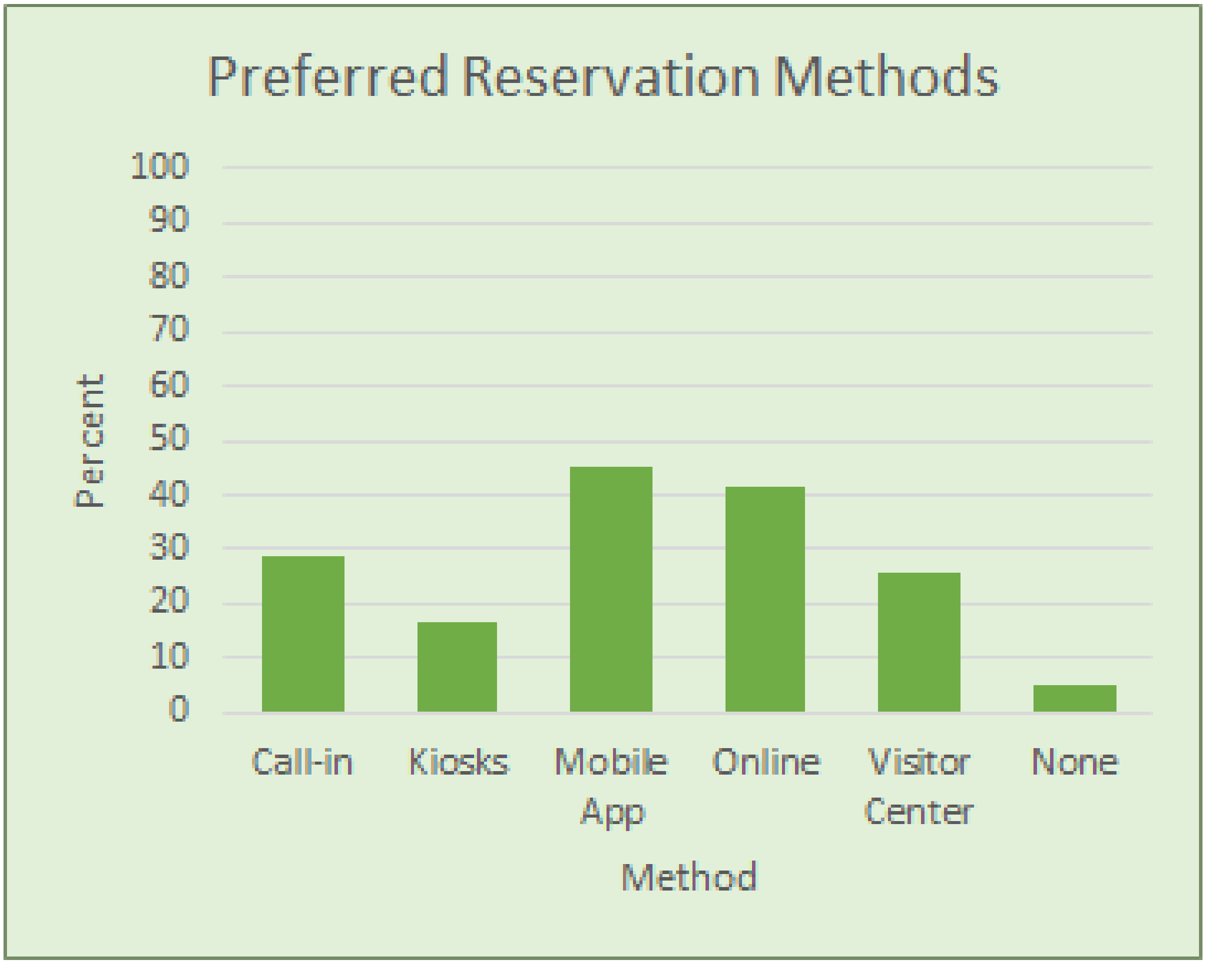

Figure 7: Preferences for Reservation Methods

Based on our surveys, most visitors would like to use some sort of online reservation system. 45% of visitors surveyed would use a mobile app for reservations and 41% of visitors would use a website, as seen in Figure 7. Calling in and reserving at the Visitor Center were the next most popular methods of reservation; 29% and 26% of visitors, respectively, would like to use these methods. Kiosks were the least popular at 16%, and approximately 5% of those surveyed did not respond to this question.

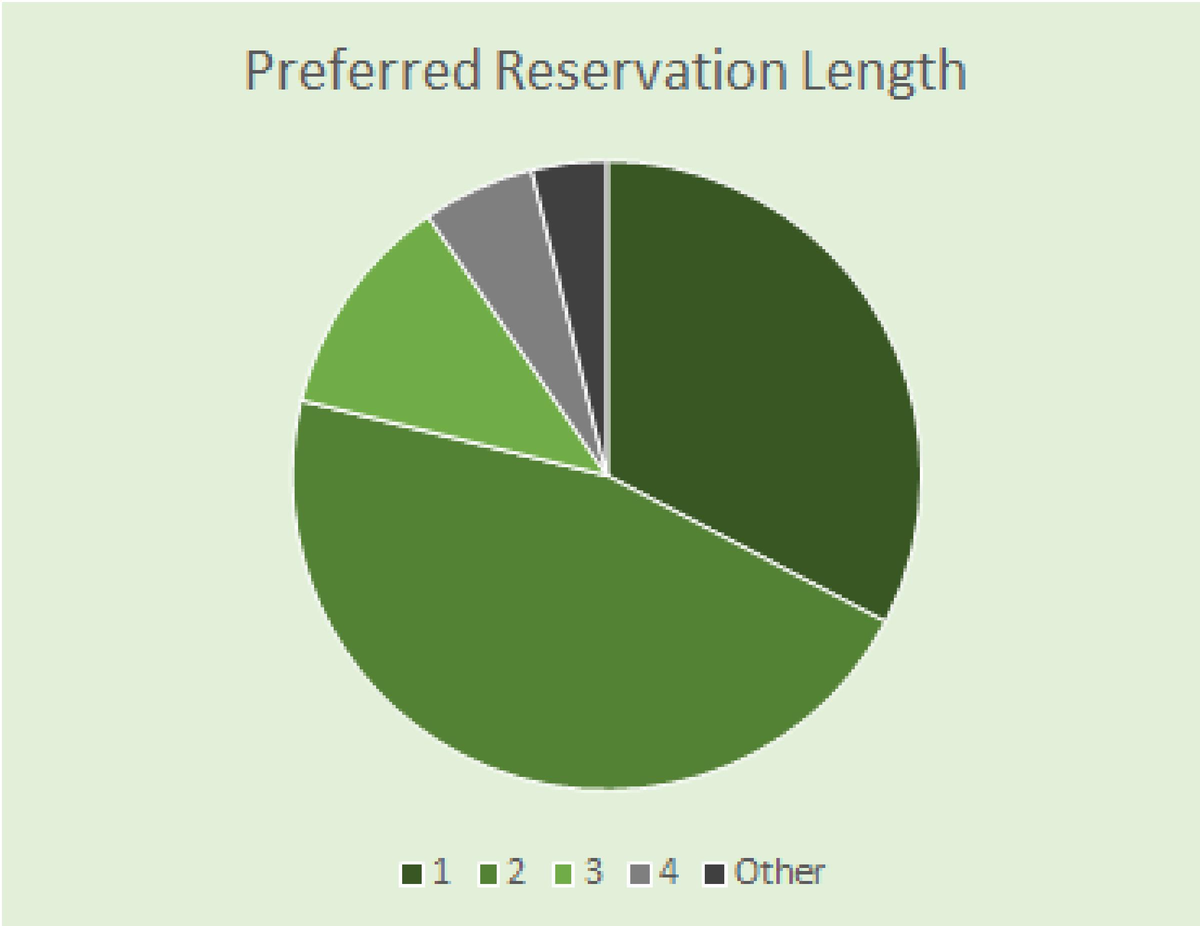

Figure 8: Preferred Length for Reservations

Most visitors preferred shorter reservation lengths. 33% preferred a length of 1 hour, 46% preferred 2 hours, 12% preferred 3 hours, and 6% preferred 4 hours as shown in Figure 8. Other responses included a desire for longer or variable length reservations.

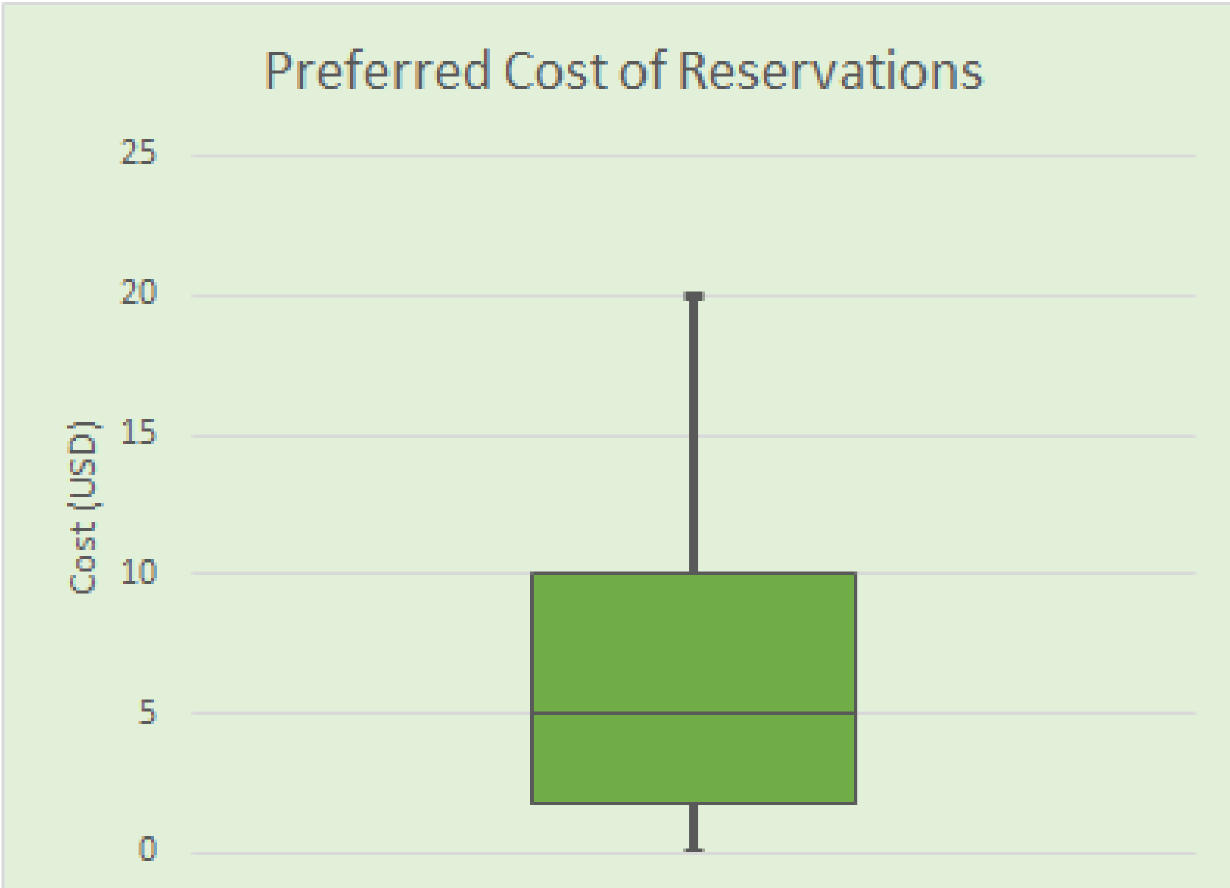

Figure 9: Preferred Cost of Reservations on Cadillac Mountain

Visitors would be willing to pay an average of $5 for a reservation, but responses ranged from not willing to pay to $20 as shown in Figure 9. One person was willing to pay as much as $50.

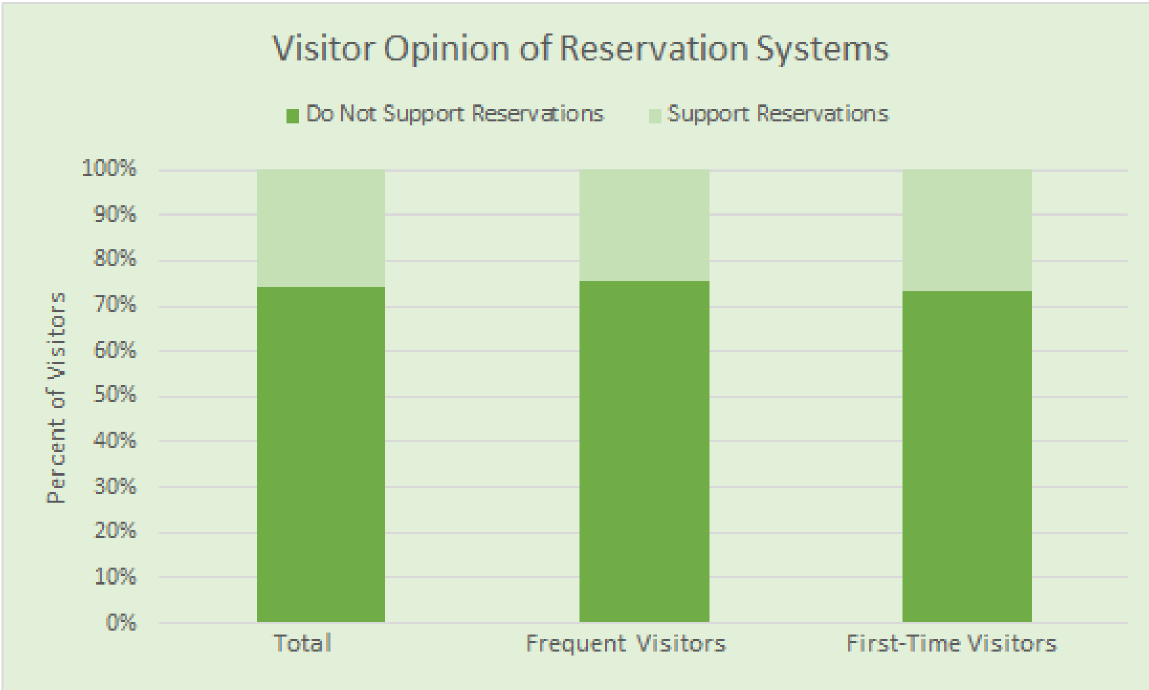

Figure 10: Do Visitors Want Reservations?

There was no correlation between the number of times a visitor had been up the mountain and their opinion on a reservation, as shown in Figure 10. For both first-time and repeat visitors, approximately 25% of visitors would rather have reservations than first come, first serve parking.

Average Parking Length

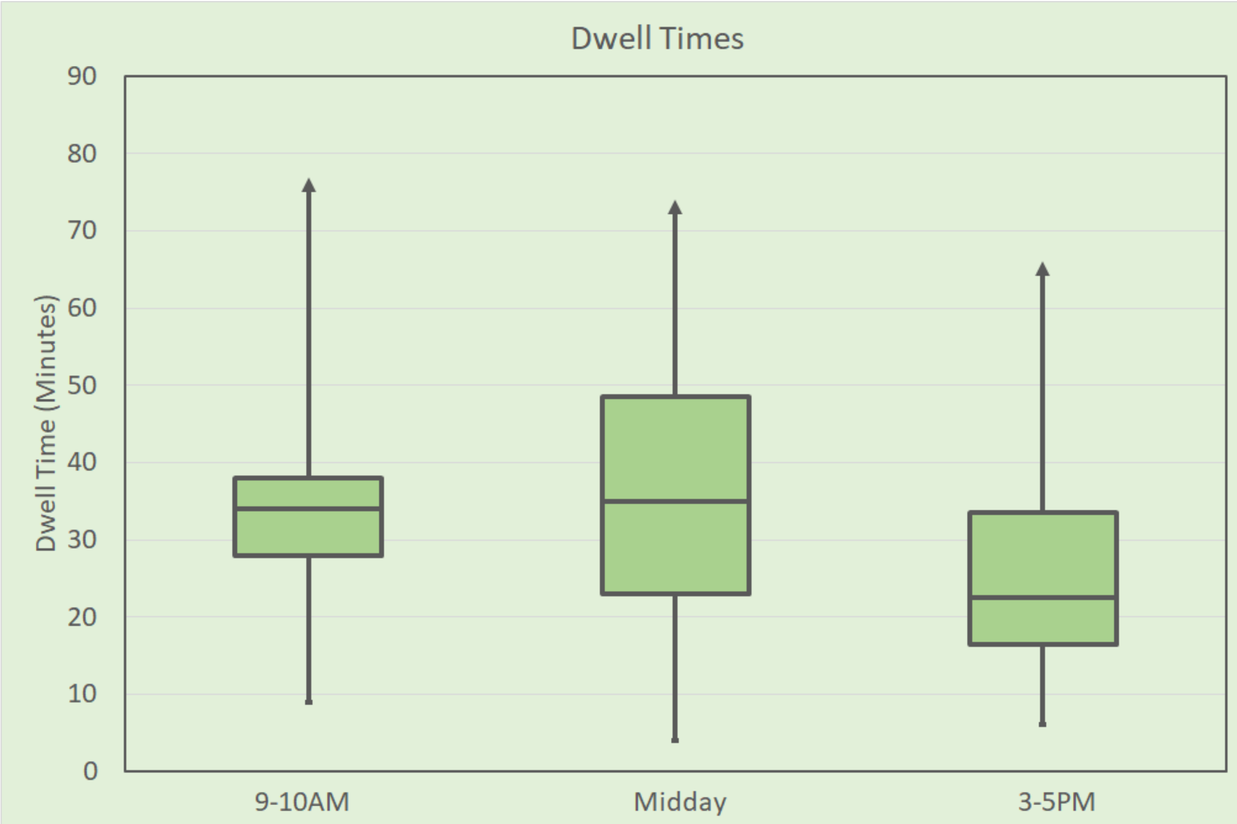

Figure 11: Average Dwell Times at Cadillac Mountain Summit

Dwell times averaged just over 30 minutes in the morning and midday, as illustrated in Figure 11. The dwell times in the afternoon were shorter, averaging 22.5 minutes. The standard deviation for all times was approximately 15 minutes. Cars left within 30 minutes of sunrise and sunset respectively.

Fee Compliance

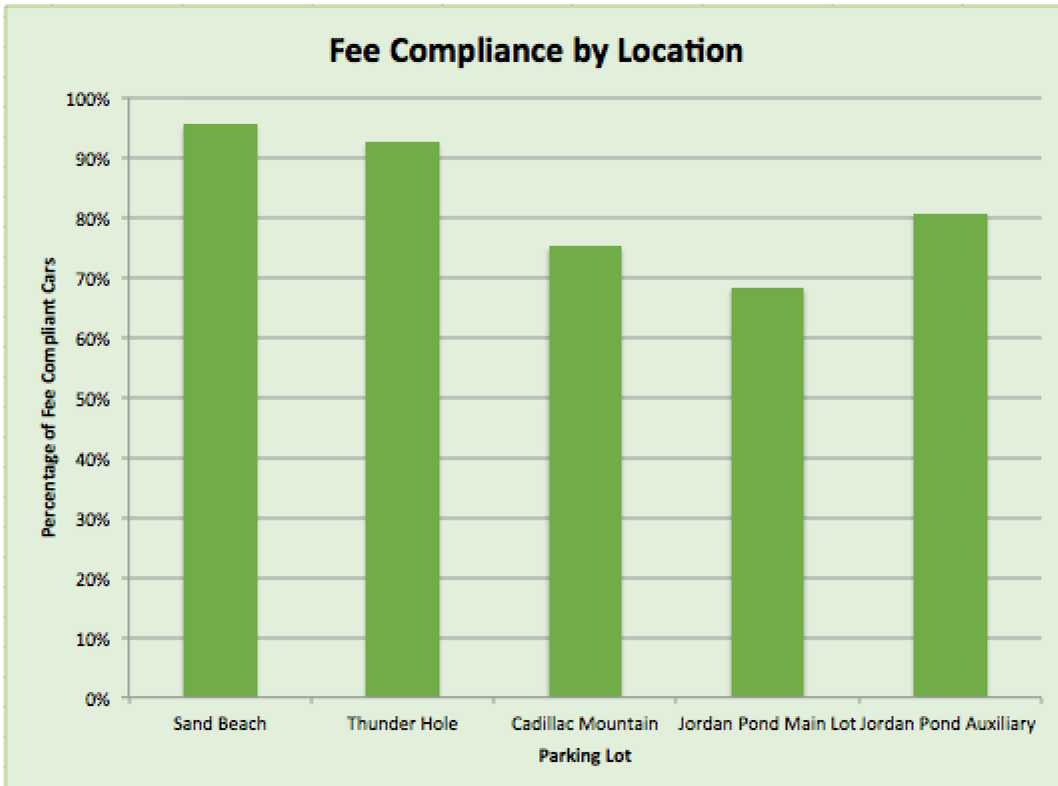

Figure 12: Fee Compliance Percentages along Park Loop Road

Compliance was high along the one-way portion of Park Loop road, due to the need for a pass to get through the entrance station before Sand Beach. Considering the fact that Sand Beach and Thunder Hole were on average 94.75% compliant and every guest needs a pass to reach this point, a 5.25% threshold could be used at other locations to standardize fee compliance. Jordan Pond had the highest non-compliance ratio of 24.5% due to the presence of restaurant guests. Cadillac Mountain only had a 15% non-compliant rate despite the fact that passes were not checked to reach the summit. This information is shown in Figure 12.

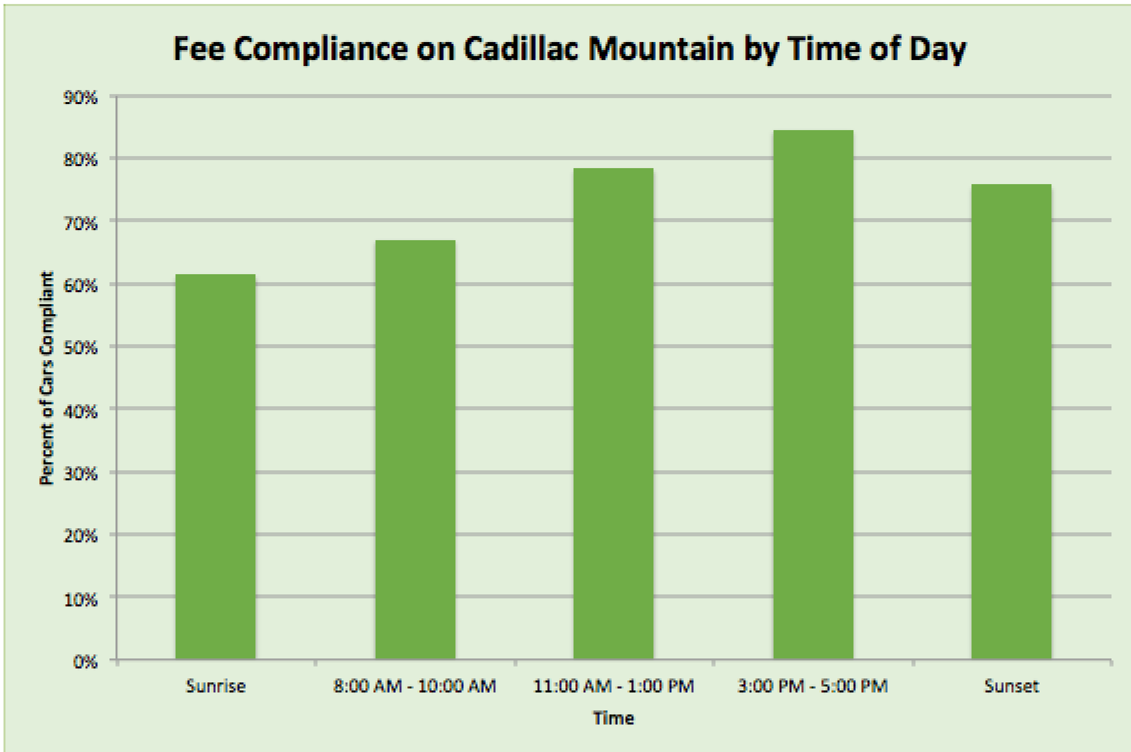

Figure 13: Fee Compliance Percentages on Cadillac Mountain by Time of Day

As Figure 13 shows, fee compliance on Cadillac Mountain was lowest at sunrise (61.4%), as passes cannot be purchased from the Visitor Center at this time. Compliance peaked in the afternoon (84.6%) and decreased for sunset (75.7%).

Dwell Times at Gates

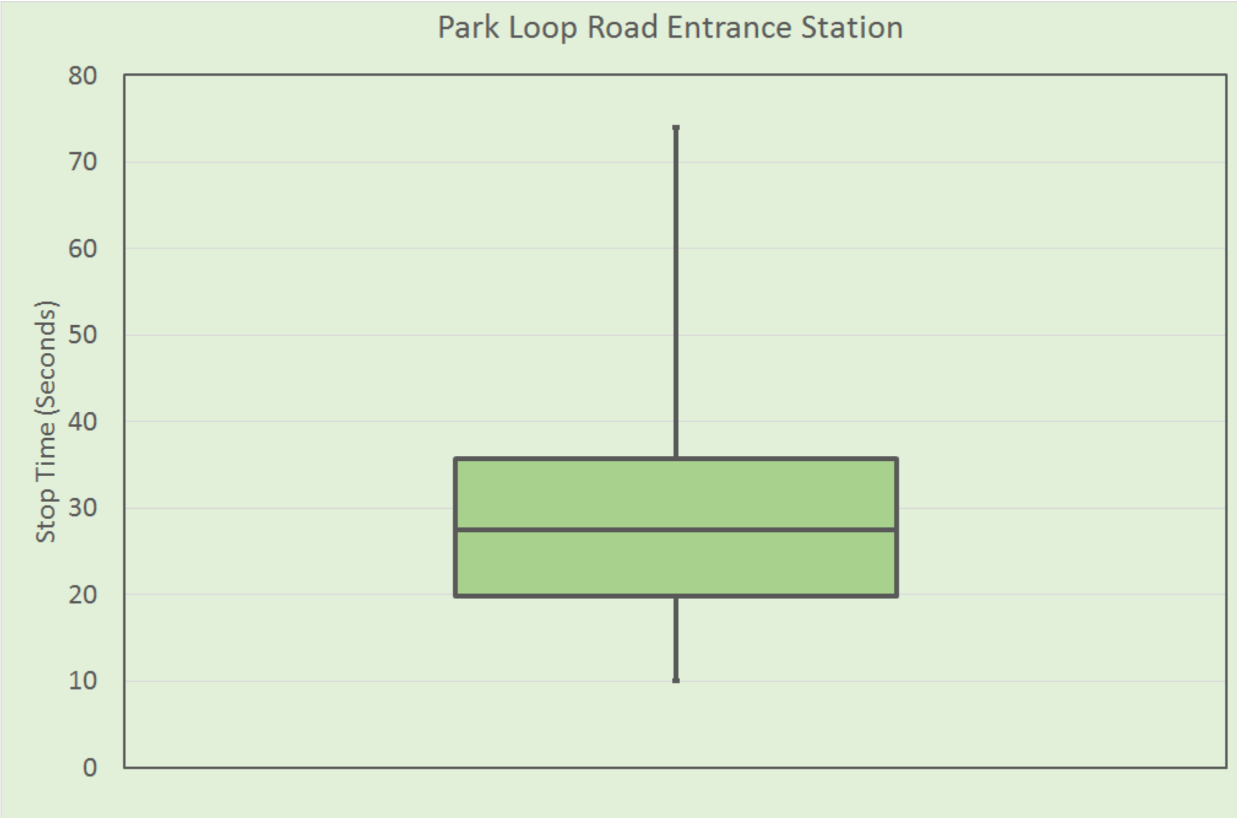

Figure 14: Dwell Time at Park Loop Road Entrance Station

Cars stopped at the entrance station before Sand Beach for an average of just under 30 seconds, as displayed in Figure 14. This included the time to buy or show a pass and receive information from park staff. However, some visitors took as long as three minutes to gain entry to the park and get directions.

Analysis

Potential Solutions

Time Slots

Peak Time

This solution's primary focus is to move congestion away from peak times throughout the day when the mountain is most likely to be shut down, while still allowing the same quantity of visitors to come to the park by forcing them into non-peak times throughout the day. This is due to a decrease in visitors during the non-peak hours of the day, when there are empty parking spaces throughout the parking lot. This decrease can be seen in the non-tinted gaps in Figure 15, where there are fewer VAOT, or Visitors at One Time, than in the tinted peak time before it. For maximum efficiency, the visitors arriving at any one time should be constant, and just below the carrying capacity of the summit. However, by not restricting the non-peak times, those times could experience overcrowding from visitors against making a reservation.

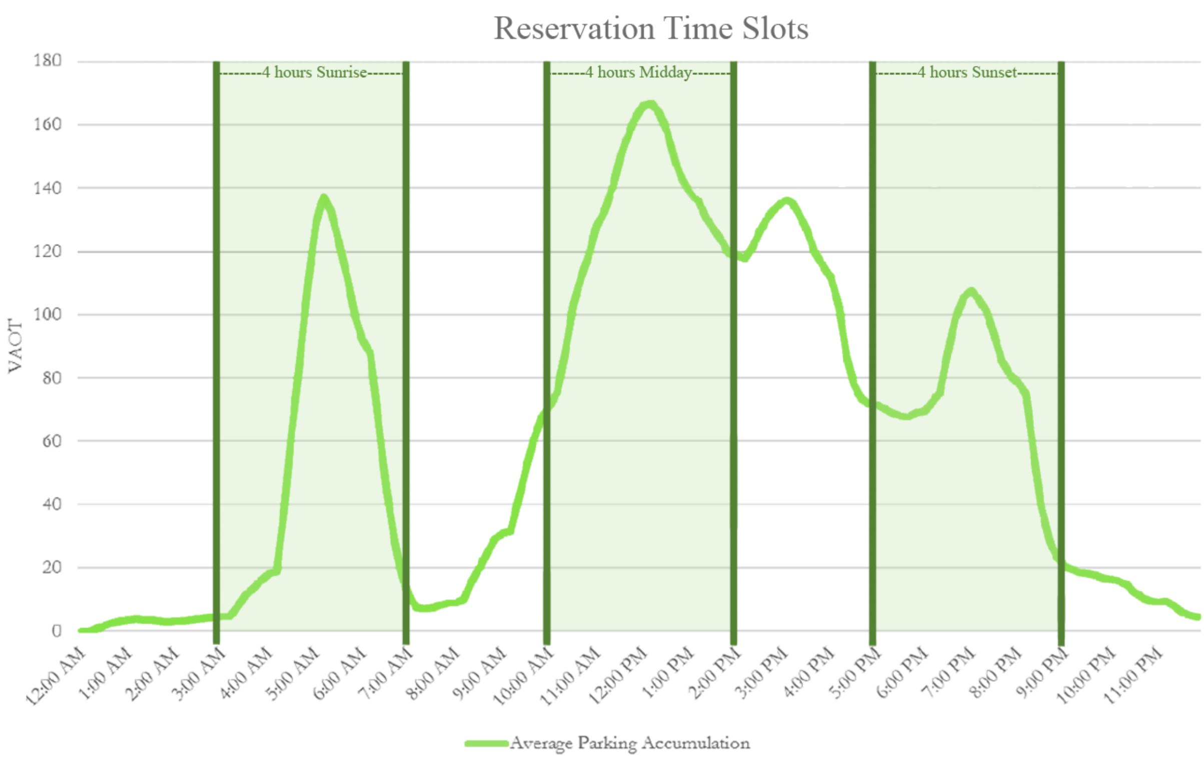

Figure 15: Recommended Reservation Time Slots (RSG, 2016)

Full Day

With a full day reservation, visitors could reserve an entire day on the mountain, allowing them to travel up to Cadillac Mountain at any time they desired. While this reservation system would provide the most flexibility to individual visitors, it would drastically decrease the number of visitors who could visit the mountain in a day. However, if a visitor wanted to see Cadillac Mountain throughout the day, they would be able to return to the summit throughout the day and know they would have a place to park every time.

Variable Length

In a variable length system, visitors would be allowed the choose the length and time of the reservation they wish to purchase. This solution aims to provide visitors with flexibility while also allowing more visitors onto Cadillac Mountain than a full day reservation system. Tourists would be able to reserve a time slot at a minimum of one hour, and extending in one-hour increments, for as long as the tourists feel they would want to spend on Cadillac Mountain. The available times could include sunrise and sunset (3am-9pm), exclude sunrise and sunset (7am-5pm) or only include peak midday times (10am-2pm). Each hour time slot would have a cost associated with it, and longer reservations would cost more per hour. This system would effectively manage visitors with interests in different activities on Cadillac Mountain such as hiking or sight-seeing.

Fast Pass

This system seeks to maximize the efficiency of the Cadillac Mountain parking lots at all times. It works based on a computer-estimated time that is generated whenever a car makes a reservation. Similar to Disney's FASTPASS™, the cars would then have to explore the rest of the park and return when their reserved time is available (Disney, 2017). However, this system is quite complex, requiring: sensors for every car entering and exiting the road; a computer to estimate future arrival times; a queue lane for cars driving up the road; a second passing lane for cars travelling up the road with the correct timed pass; and a large enough turn around area for cars to leave the line and explore the rest of the park.

Physical vs. Statistical Slots

All of the above reservation systems could determine the number of passes sold per time slot based upon either a physical or statistical approach. In a physical reservation approach, the amount of reservations sold for any given time slot is based solely upon the number of parking spaces available. For Cadillac Mountain, this means 158 spots would be available for reservation in each time slot. This method ensures that there are never too many cars on Cadillac Mountain, as there would be one parking space for each reservation. However, if the visitors are not parked on the summit of Cadillac Mountain for the full length of their reservation, they are holding an empty space that could have potentially been filled by another visitor’s car, thus preventing the parking lot from reaching its maximum capacity at all times throughout the day. The physical reservation method would be most efficient as the time slot length approaches the average dwell length, as each parking space would be filled for most of every reservation period. However, shrinking reservation time slots to become closer to the average dwell time atop Cadillac Mountain (approximately 35 minutes, seen in Figure 11 in Results) would not account for the time it takes for visitors to drive up the mountain, dwell at any of the scenic pull-offs on the road to the summit, or get through a gate checking reservations at the base of the mountain.

In a statistical reservation approach, the amount of reservations sold per time slot is based upon the standard deviation of the dwell time. This strategy would create more reservation spaces than there are parking spots per reservation period, under the assumption that cars will not generally spend the entire reservation time parked, and that more cars than there are parking spaces could park without conflict within a reservation period (Simon, 2013). This would allow the parking lot to be used to its maximum capacity at more times throughout the day. For example, since the average dwell times of cars atop Cadillac Mountain are approximately 35 minutes, the 25 minutes of each car’s reservation in a one-hour block not spent parked on the mountain could be filled by another car with a reservation. However, with this approach there is always a possibility that at any time during a reservation slot, cars may all arrive at the same time and a visitor would have to wait to find an available parking spot, despite having made a reservation. This probability can be statistically determined, but grows more likely as time slot lengths increase (Simon, 2013). For example, in a full day system with statistically determined reservation slots, most of the cars would likely still visit at the peak times, and many would still have no place to park. Alternatively, with a smaller reservation time slot, the visitation rate would be more predictable (Simon, 2013). A summary of the various reservation systems and slot types are shown in Table 4 below.

Reservation System	Pros	Cons
Peak Time	• Moves congestion away from peak times • Utilizes non-peak time	• Could overcrowd non-peak times
Full Day	• Flexibility for visitors	• Reduces maximum visitors • Possibility of a bottleneck
Variable Length	• Flexibility for visitors • Increases maximum visitors	• Potentially unable to get desired length
Fast Pass	• Increases maximum visitors • Allows for more flexibility	• Complex • Large queue times, multiple lanes, and turn around area required
No Reservations	• Increases maximum visitors • Flexibility for visitors	• Overcrowded • Unable to find parking spots • Road shuts down
Reservation Slot Type	**Pros**	**Cons**
Statistical Slots	• Higher number of visitors	• Lot might be oversold
Physical Slots	• Lot is never oversold	• Lower number of visitors

Table 4: Potential Reservation Systems

Making Reservations

Website

A website would be useful for visitors to reserve online before coming to the park. There would be an ability to print out a receipt with the reservation that contained all the information needed at the gate, or equipped with a scannable barcode. The website should also be mobile friendly to allow visitors to make reservations at any time, even when exploring the park.

For a web platform, the team considered Recreation.gov and an independent site. Recreation.gov is an already existing platform used by other national parks. There is a precedent for using Recreation.gov for this kind of reservation, as this is the system that the Haleakalā sunrise reservation uses (Recreation.gov, 2017). However, Recreation.gov has limited features. The user experience of the site is low in quality. Also, park staff cannot directly manage and maintain the site. Same-day reservations and other potential improvements would therefore be difficult to implement. In addition, Recreation.gov cannot currently ensure that visitors making a reservation will also have a pass valid for the date of their reservation, thus restricting the potential for 100% fee compliance.

An independent web platform could be designed to be intuitive for both visitors and staff. It could be customized, and park staff or the Friends of Acadia could have direct input into the features of the site. One feature that could be implemented on an independent site either immediately or as a future system update would be to link the reservation to a valid park pass. A possible outline for this is shown in Figure 16 below. A customized system could also be easily adapted to mobile platforms or kiosks. The major drawback for this method is the higher cost of designing and maintaining the site. Another option for the reservation system is to link them to a person rather than a park pass. We found that only the passes sold online were linked to a person (Miller-Rushing, personal communication, 2017). This would prevent people from making obsessive reservations and allow everybody to visit the park.

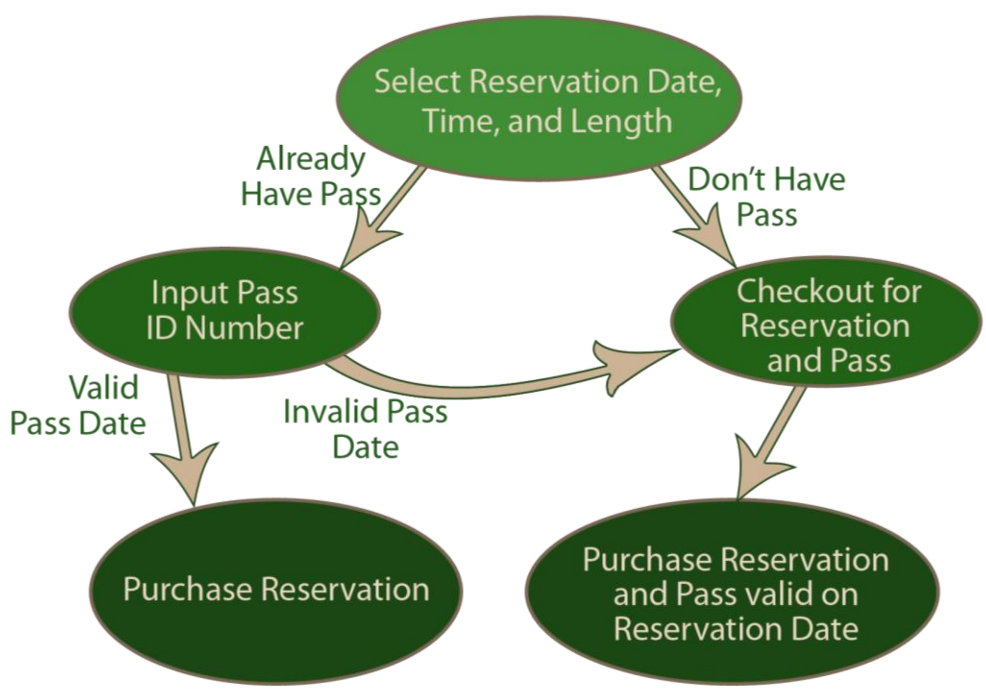

Figure 16: Potential Reservation Website Flowchart

An example of how such a website may appear to the visitor is shown in the figures below, all adapted from Baxter State Park's reservation website to reflect how such a system may appear if it were for Acadia National Park.

Figure 17: Website Calendar Interface

Upon reaching the reservation site, the user will be faced with a calendar interface, as shown in Figure 17. Days with reservations available are shown with an "add reservation" button; days that have no available reservations or have passed are indicated with a red "X" instead. A pop-up window on this screen could be implemented for selecting reservation times, if multiple time slots become available.

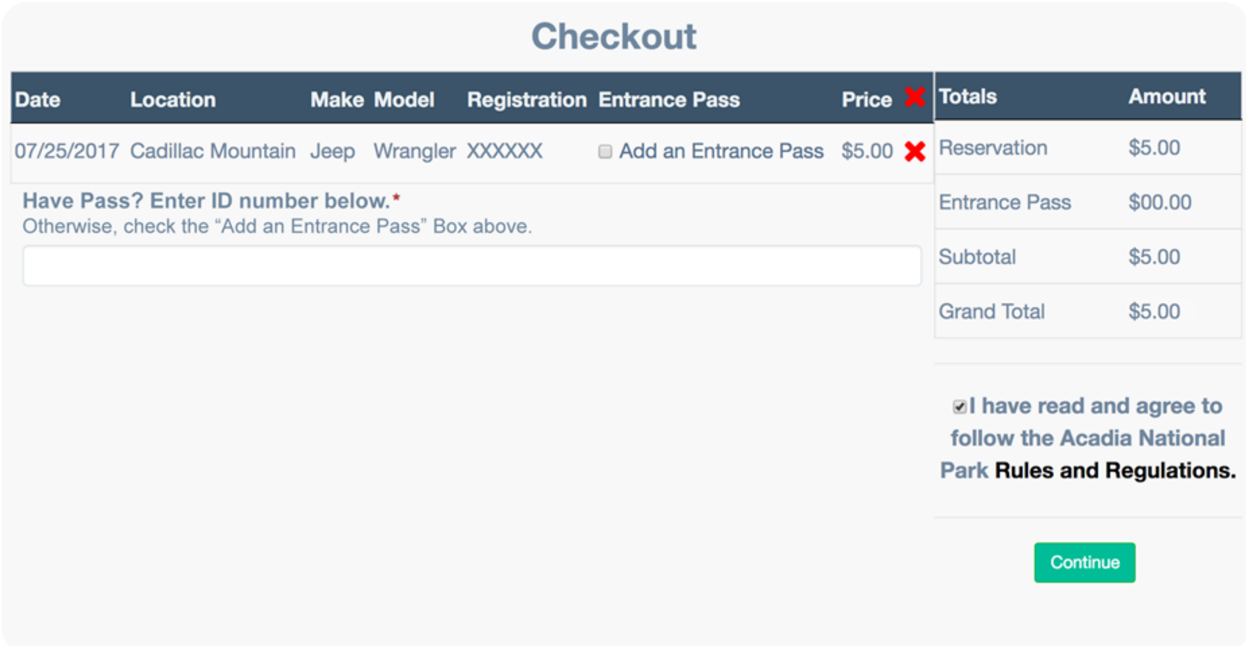

Figure 18: Registration Page for Passholders

After selecting a date and time, the user is brought to a registration page, as shown in Figure 18. On this page, they will enter vehicle registration information (or user information, if the park does not choose to implement a vehicle registration system). They will also be prompted to enter a valid entrance pass ID number or purchase a valid pass with their reservation.

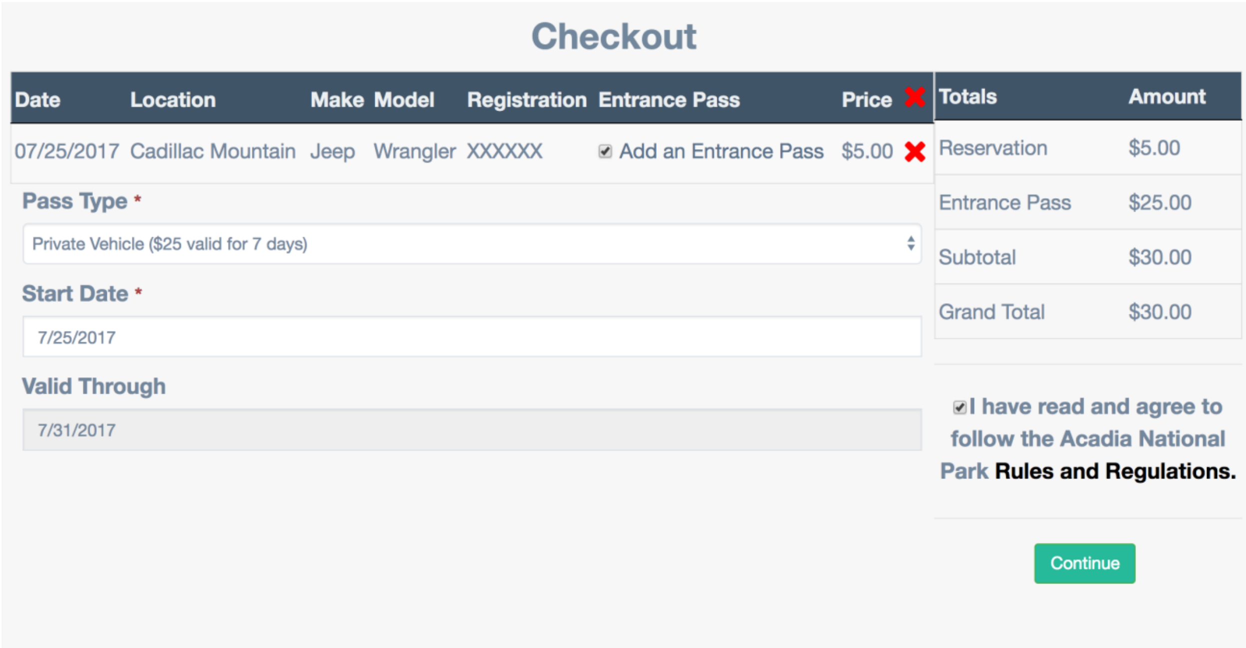

Figure 19: Registration Screen for Non-Passholders

If the user decides to purchase a pass with their reservation, they will be allowed to choose their pass type, along with the date range their pass is valid for, provided that the date of the reservation is in this range, as shown in Figure 19. Before moving onto the next page, the user must agree to the Terms and Conditions.

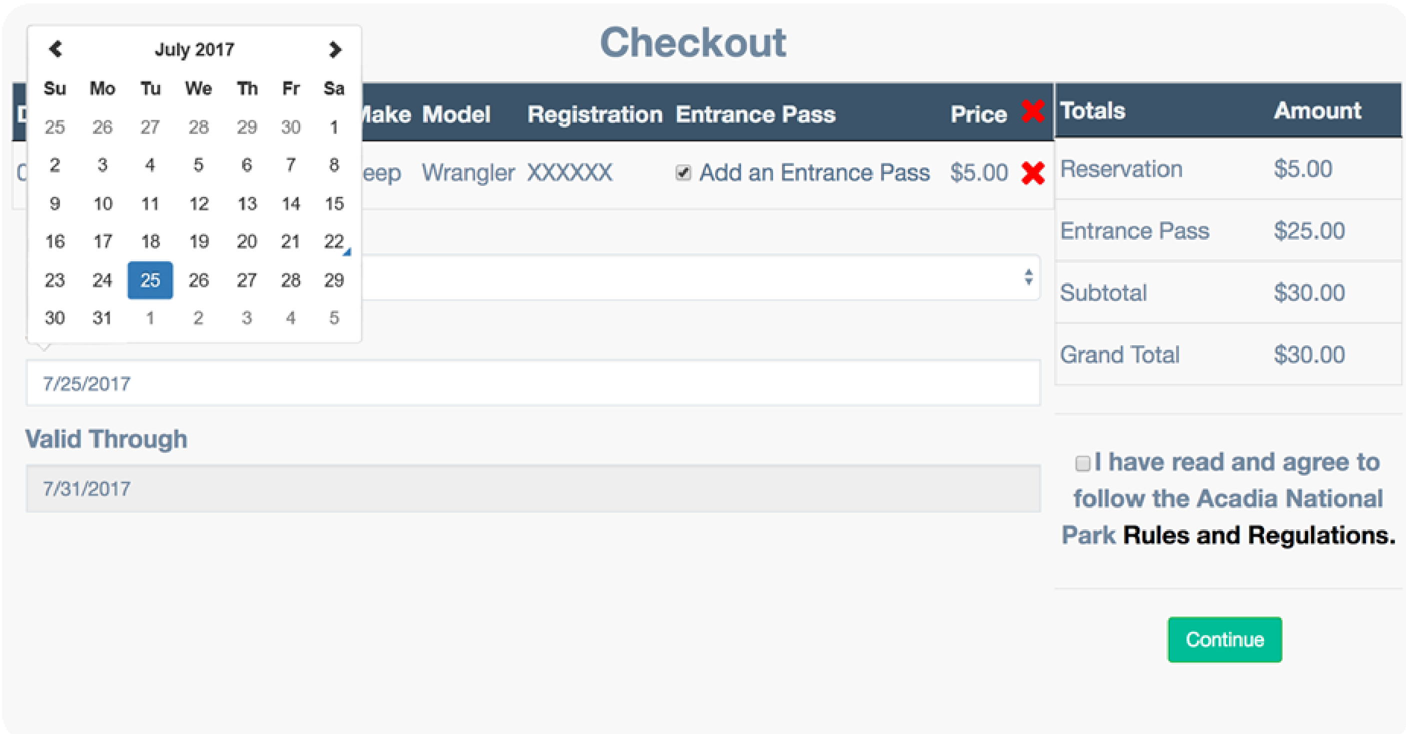

Figure 20: Pass Date Selection

If the user does not want the default range for pass start and end dates, a pop-up calendar interface allows for the selection of a new start date, as shown in Figure 20. The user simply clicks on the start date they would like. The end date will change automatically to reflect the length for which the pass is valid, given the new start date.

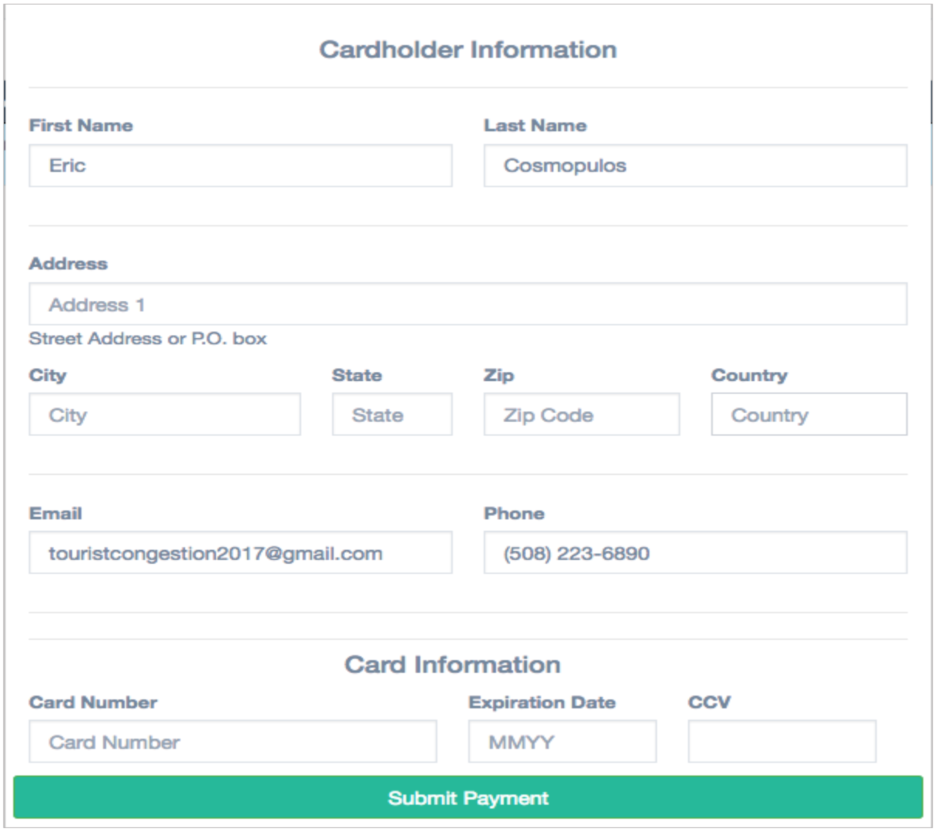

Figure 21: Checkout Page

Finally, the user will be brought to a checkout page, where they will enter valid payment and contact information as shown in Figure 21. After submitting this information they will be sent a confirmation email containing a QR code needed to access their reservation, similar to the one shown in Figure 22.

Figure 22: QR Code Example

Mobile App

A mobile app would streamline the reservation process. An app would display the timestamp from the reservation as well as a barcode for use at the base of Cadillac Mountain. It would also be able to direct the visitor to a booking calendar with available reservation times as well as an option for payment methods. It would be additionally helpful if the designed app included the ability to show the barcode, QR code or confirmation notice for the reservation while offline, in case the visitors using the app did not have reception when they needed to show proof of their reservation.

Kiosks Throughout the Park

Electronic kiosks would be available throughout the park, in locations such as the Visitor Center, to streamline the reservation process. The kiosks would have a simple screen where a visitor could view available reservation times and book a slot with a credit card or cash. A receipt could then be printed with a time stamp and barcode, allowing the ranger at the base of Cadillac Mountain to verify visitors' reservations.

Call-in

Visitors could potentially have the opportunity to call-in to a reservation hotline and either make their reservation via automated prompts or talk to a representative from the park. This method would be particularly accessible to the certain members of the population, as it requires limited technology and resources. Visitors could book their trip and receive a confirmation email or pick up their confirmation at the Visitor Center for use at the Cadillac Mountain gate.

Visitor Center

Visitors could also be directed to the Visitor Center, where a ranger would assist them in making a reservation. Rangers would have access to a centralized system which would inform them of the number of available reservation slots in a given time range. This would allow visitors who would struggle through using an online system themselves to still easily make a reservation in person. Using existing services available at the Visitor Center, this would allow visitors to obtain information about the system and the park as a whole and also purchase a park pass at the same time. Alternatively, kiosks could be placed inside the Visitor Center for a streamlined online experience, and rangers can assist customers who struggle with the technology.

Gate System

There are several options to consider for the gate system at the base of Cadillac Mountain, which would be necessary in order to ensure compliance with reservations at each time. These options include manned gates and automatic gates, and also introduce the issue of how many lanes would be needed to minimize queue times while still preserving as much of the natural environment as possible.

Manned Gates

A manned gate, such as the one shown in Figure 23, would require a gatehouse at each lane and park personnel in each one to check the passes of the visitors. Gatehouses would also require space beside the road on the driver's side, in order to allow visitors to easily offer their reservation slips to park rangers to get up the mountain. However, as this would necessitate space between the lanes of the road equal to the size of a gatehouse, substantial widening of the road and replacement of some of the natural environment with pavement would be necessary. In addition to these immediate monetary and environmental costs, it would require the continual fixed cost of paying park rangers to man the gatehouses. However, the initial costs of a manned gate would be less expensive than an automatic gate.

Figure 23: Manned Gate (Bushatz, 2017)

Manned gates offer flexibility in unexpected scenarios, such as when a visitor has a reservation in an undetectable format. In addition, dealing with a human being may be less confusing to some people, as a ranger can provide clarity that an automated system could not. Having a person with which to interact, however, makes queue times at the gates longer than with an automatic gate. The average visitor spent just over 30 seconds at the gatehouses to the Ocean Drive portion of Park Loop Road. This process includes asking for park information, buying a pass, or verifying your pass. Several visitors idled for longer than two or even three minutes to converse with park rangers. This means that since it takes longer to process each visitor, queue lengths will grow as visitors wait to be admitted up the mountain.

Automatic Gates

With automatic gates, each entry lane would need an electric-powered automatic gate, such as the one in Figure 24, along with a scanner capable of reading the form of information transfer the reservation receipts would contain, such as a QR code. It has high initial costs compared to manned gates, but it would not require the space of a gatehouse, limiting destruction of natural resources.


Figure 24: Automatic Gate (“Engineered Parking Systems”, 2017)

Automatic gates would not allow visitors to interact with park personnel, so the time spent at the gate would be greatly diminished and would allow visitors to move through the gate faster, reducing queue lengths. There would be fewer gate attendants for the park to employ during reservation times, although there would likely have to be a single gate attendant stationed at the base of Cadillac Mountain in case a car needed assistance or there was a malfunction at the gate. However, in unusual situations such as a visitor having accidentally rendered their reservation receipt unreadable to the gate, an automatic gate could be inflexible in handling the situation and may lead to visitor irritation.

Number of Lanes

For either type of gate, the number of lanes needed to effectively manage the queue lengths of the visitors must be addressed. While more lanes would mean smaller queues and shorter queue times, it also requires a larger environmental impact due to necessary road expansion. Since manned gates are less efficient than automatic gates and people spend more time at these gates, queues would be longer and therefore more lanes would be needed. An automatic gate, on the other hand, could handle cars more efficiently and would require fewer lanes to manage queue backup.

Simulation Modeling and Analysis

To determine the optimum number of lanes for each kind of gate, the team used a simulation modeling and analysis software called Arena. Three models, which represent realistic situations if a gate or gates were to be constructed at the base of Cadillac Mountain, were created from observational data consisting of the queue lengths at the Ocean Drive Gate and the interarrival times of cars to Cadillac Mountain for sunrise. To measure the success of each option, three metrics were used: queue length, queue time and run completion time. The three most feasible solutions were chosen based on their cost effectiveness as well as their environmental impacts and infrastructure allotment. Below are representations of the longest queue lengths based on their respective models.

Figure 25: One Automatic Gate Google Earth Representation

Figure 25 shows the maximum queue length of eight at any given time based on the one automatic gate Arena model. As can be seen in the figure, placing this gate near the base of Cadillac Mountain where the road is wider could potentially lead to backups encroaching on the main road in a worst-case scenario. Cars spent an average of 19 seconds in the queue, and all 150 the cars in the model were processed by the gate within 45 minutes.

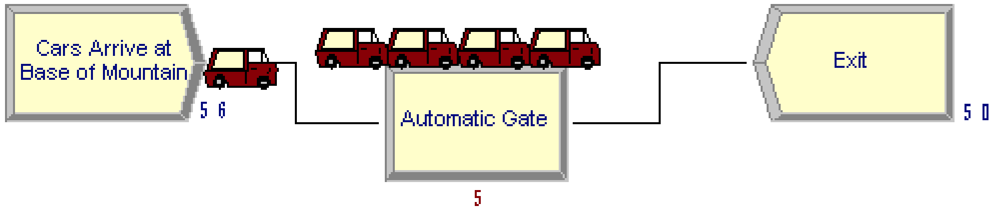

Figure 26: One Automatic Gate Arena Model

The Arena model in Figure 26 depicts the middle of the process of moving cars through one automatic gate. Cars arrived at the base of the mountain with a random exponential distribution with a mean of 17 seconds. Then they were processed at the gate using a normal distribution with a mean of 10 seconds and standard deviation 10 seconds.

Figure 27: Two Automatic Gates Google Earth Representation

Figure 27 shows the maximum queue length of one at any given time based on the two automatic gate Arena model. There are two cars at each lane because the queue is considered all of the cars not currently processed by the gate. The average time spent in the queue was five seconds, and all cars were processed within 45 minutes.

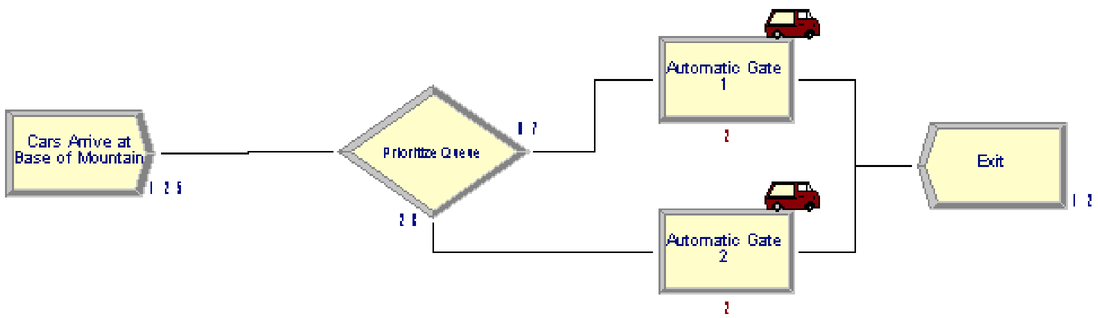

Figure 28: Two Automatic Gates Arena Model

The Arena model in Figure 28 depicts the middle of the process of moving cars through two automatic gates. First, cars arrived at the base of the mountain with a random exponential distribution with a mean of 17 seconds. They then met a decision module in which they chose the gate with the shortest number of cars in the queue. They were processed at the gate using a normal distribution with a mean of 10 seconds and standard deviation of 10 seconds.

Figure 29: Three Manned Gates Google Earth Representation

Figure 29 shows the worst-case maximum queue length of 4 at any given time based on the three manned gate Arena model. The average time spent in the queues was 32 seconds, and all cars were processed within 49 minutes.

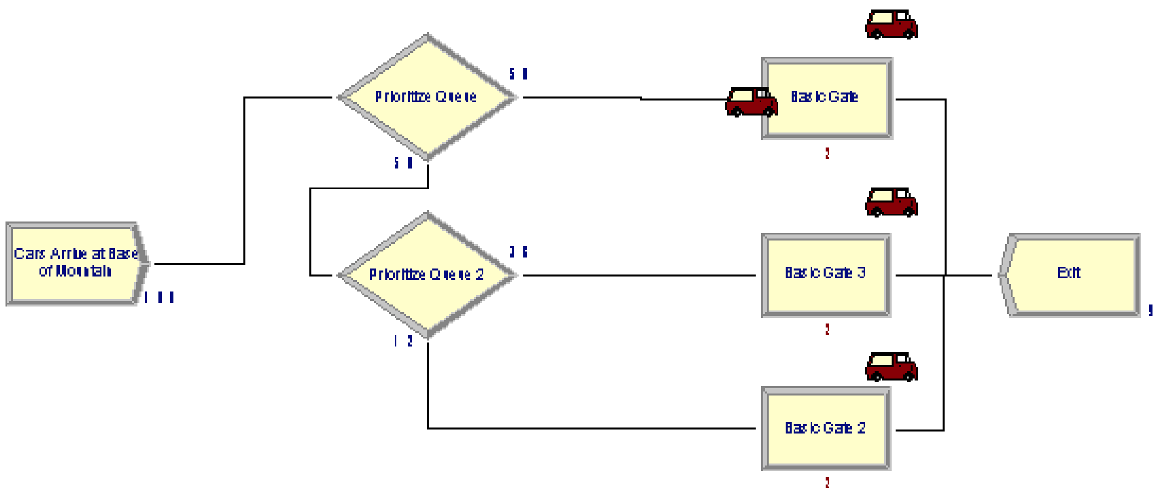

Figure 30: Three Manned Gates Arena Model

The Arena model in Figure 30 depicts the middle of the process of moving cars through three manned gates. First, cars arrived at the base of the mountain with a random exponential distribution with a mean of 17 seconds. They then met a decision module in which they either continued to Gate 1 if there were less cars there than in Gate 2 or 3. If there were more cars in Gate 1 they moved to the second decision module in which they prioritized Gate 2 and 3 based on the current numbers in the queues. They were then processed at the gate using a normal distribution with a mean of 33 seconds and standard deviation of 27 seconds.

Data from the Arena models is summarized in Table 5 above. One manned gate is the only system that failed to get 150 cars through in an hour, but the average queue time for two manned gates is lengthy, thereby rendering the gate inefficient.

Gating System	Maximum Cars in Queue	Average Cars in Queue	Maximum Time in Queue (s)	Average Time in Queue (s)	Time Allotted
2 Automatic Gates	1	0	35	5	45 Minutes
1 Automatic Gate	8	1	90	19	45 Minutes
3 Manned Gates	4	1	143	32	49 Minutes
2 Manned Gates	9	4	316	162	48 Minutes
1 Manned Gate	80	45	1635	1014	1 Hour

Table 5: Model Data Summary

Cost-Effectiveness Analyses

Reservation systems

Full Day

A full day reservation is not well suited for Cadillac Mountain, as the dwell times are much lower than a day, as seen in Figure 11 (page 43, Results). Most places that have implemented full day reservation systems have activities that last all day or several days, such as camping. For Cadillac Mountain, a full day system would heavily restrict the number of cars capable of driving up the mountain, and as a result would not be ideally suited for the volume is visitors visiting the park.

Fast Pass

Most places employing a Fast-Pass system have fixed-length activities; however, Cadillac Mountain has a high variance of dwell times, as shown in Figure 11 (page 43, Results). Accordingly, the team determined that a Fast-Pass style of solution would not be feasible, as the return times for visitors turned away would be difficult to calculate.

Statistical Reservations

The team found statistical reservations to be undesirable for Cadillac Mountain. The high variance of dwell times at Cadillac Mountain, shown in Figure 11 (page 43, Results), would cause difficulties in estimating the amount of parking spaces to overbook. It would be detrimental to the visitor experience if one were to reserve a spot but then find none available upon arrival. Additionally, the team witnessed visitors wishing to see sunrise or sunset were all present for the sunrise or sunset, then left within half an hour after. As statistical reservations would rely on visitors arriving at different times within the reservation block, they were determined impractical for these peak times.

Peak Time and Variable Length

Since other reservation systems were determined unfeasible, the team only examined costs for peak time and variable length reservation systems. However, the variable length system is not viable for sunrise and sunset as discussed in the section above. Similarly, a peak time system would not be viable for midday, as the dwell times, shown in Figure 11 (page 43, Results), are much shorter than the length of the peak hours. As a result, we investigated a combination of peak time and variable length systems. The peak times were used for sunrise and sunset, while a variable length system was used for the midday hours. The team decided one-hour time blocks would be best based on the dwell times observed and the results of the surveys, shown in Figure 8 (page 40, Results). While the survey suggested visitors would prefer two-hour time blocks, one-hour time blocks were closer to the observed dwell times, and the nature of a variable length system would allow visitors to still reserve two one-hour blocks if desired.

Costs

Gates and Road

An article prepared for the U.S. Department of the Interior established the cost to construct an automatic gate to be as much as $100,000 (John A. Volpe National Transportation Systems Center, Research and Innovative Technology Administration, & U.S. Department of Transportation, 2011). The cost for a manned gate was estimated based upon the average cost per square foot to build a home, $150, leading to an estimate of $17,500 per gatehouse ("How Much does it Cost to Build a House?", 2017). Costs for expanding the road were based upon the $4.4 million cost to pave a one mile of a four-lane highway, resulting in an estimate of $62,500 per lane ("Construction Advertisement Plan", 2017).

Independent Website

The team decided using Recreation.gov would not be viable due to its low usability, creating a negative visitor experience, and its lack of functionality in guaranteeing fee compliance. As a result, the main focus was costs and benefits for an independently run website for online reservations. It was found that an advanced website such as the one Acadia National Park would use would cost approximately $30,000 to design and run (Katkin, 2015). Additionally, an independently run website would afford more ease in expanding the system than Recreation.gov, as it could be extended to be compatible with other methods of reservations including mobile applications or kiosks throughout the park.

Benefits

Reservation fee

A reservation fee serves two purposes. The first is to help pay for the costs to implement and maintain a reservation system. The second is to ensure visitors do not make obsessive reservations, only registering for time blocks they intend on going to rather than making as many as possible. Based on the survey results shown in Figure 8 (page 40, Results), the team believes a $5.00 fee would be best. However, this could be adjusted to charge more for busier times of the day in higher demand or charge less for underutilized times, encouraging reservations to be evenly spread throughout the day.

Increased fee compliance

Another benefit of the reservation system is its ability to guarantee 100% fee compliance. Since there must be a system in place to verify reservations at Cadillac Mountain, by linking park passes to the reservations, anyone with a reservation must have a pass, and fee compliance is ensured. The calculations for increased fee compliance assume visitors purchase the private vehicle entrance pass, lasting a single week and costing $25, and that each visitor only makes a reservation once during the time in which their pass is valid. The calculations for monetary benefits at the peak times are detailed in Table 6 below, and are used for each plan, as the times and cost of reservations for visitors would remain the same in each scenario.

Benefits (Estimated Per Month)				
Reservations	**Time**	**Incr. Fee Comp.**	**Res. Fee**	**Total**
	Sunrise	$45,700.00	$23,700.00	$69,400.00
	Sunset	$28,700.00	$23,700.00	$52,400.00
	4-hour Midday	$102,000.00	$94,800.00	$196,800.00
	Total	$176,400.00	$142,200.00	
			Total Benefit:	**$318,600.00**

Table 6: Benefit Analysis

Plan 1

The first plan is to have two automatic gates and an independently run website with the capability of linking to the park passes to ensure fee compliance. The total cost and benefits for this plan are shown in Table 7 below. This plan uses an automatic gate because of its fast processing times and shorter queue length. This plan has the lowest worst-case queue lengths of the three plans considered, leading to the best impact on visitor experience. However, this plan is also the most expensive one. It has only moderate environmental impact from road expansion, but still requires a single additional lane.

Plan 1 Cost-Effectiveness Analysis				
Category	**Item**	**Quantity**	**Price**	**Total**
Website	Independent Website	1	$30,000.00	$30,000.00
Gates	Automatic Gate	2	$100,000.00	$200,000.00
	Road	1	$62,500.00	$62,500.00
			Total Cost:	**$292,500.00**
			Total Benefit:	**$318,600.00**

Table 7: Plan 1 Cost-Effectiveness Analysis

Plan 2

Similarly, the second plan has the same website as the first plan, but only a single automatic gate. The total cost and benefits for this plan are shown in Table 8. This plan only uses a single automatic gate, thus having lower processing times and higher queue lengths than the first plan. Additionally, there is no need to expand the road further, resulting in the smallest environmental impact. However, this plan also has the worst visitor experience due to the longest worst-case queue times. This plan could still be viable if placed further up the road but would require road expansion for a turn around.

Plan 2 Cost-Effectiveness Analysis				
Category	**Item**	**Quantity**	**Price**	**Total**
Website	Independent Website	1	$30,000.00	$30,000.00
Gate	Automatic Gate	1	$100,000.00	$100,000.00
	Road	0	$62,500.00	$0.00
			Total Cost:	**$130,000.00**
			Total Benefit:	**$318,600.00**

Table 8: Plan 2 Cost-Effectiveness Analysis

Plan 3

The third plan is to have the same website as the other two plans, but with three manned gates. The total cost and benefits for this plan are shown in Table 9. Due to the decreased efficiency of manned gates as compared to automatic gates, the team did not investigate a cost-effectiveness analysis for one- or two-lane manned gates. Three-lane manned gates have a moderate queue length compared to the other plans, leading to moderate visitor experience in an effectiveness comparison. Since this plan requires two additional lanes, it also has the worst environmental impact of the plans.

Plan 3 Cost-Effectiveness Analysis				
Category	**Item**	**Quantity**	**Price**	**Total**
Website	Independent Website	1	$30,000.00	$30,000.00
Gate	Manned Gate w/House	3	$17,500.00	$52,500.00
	Road	2	$62,500.00	$125,000.00
			Total Cost:	**$207,500.00**
			Total Benefit:	**$318,600.00**

Table 9: Plan 3 Cost-Effectiveness Analysis

Conclusion

Recommended Solution

The team recommends Plan 1, two lanes of automatic gates with an independently run website. The costs and benefits for this plan are reviewed in Table 10 below. Reservations would be made at peak times and based on the physical number of parking spaces available rather than overbooking. We believe this would be the best of each of the plans as it minimizes the impact on the visitor experience through wait times most effectively and, while it does require road expansion and removal of natural resources, it would not require as much additional space as Plan 3, with the three manned gate lanes. This system, with its small queue sizes and wait time, could also be more easily placed near the base of the mountain, where the road is already wider, further minimizing the environmental cost to expand the road. A visual representation of the recommended plan is provided in Figure 31.

Recommended Solution Cost-Effectiveness Analysis				
Category	**Item**	**Quantity**	**Price**	**Total**
Website	Independent Website	1	$30,000.00	$30,000.00
Gates	Automatic Gate	2	$100,000.00	$200,000.00
	Road	1	$62,500.00	$62,500.00
			Total Cost:	**$292,500.00**
			Total Benefit (without Midday):	**$121,800.00**

Table 10: Recommended Solution Cost-Effectiveness Analysis

Figure 31: Recommended Solution Representation

In this system, reservations would be purchased through an independent online reservation website, potentially through Acadia National Park's own website or as a part of the Friends of Acadia website. In order to minimize queue time and congestion at the base of Cadillac Mountain, the proof of reservation should be displayable via a printable receipt containing a QR code which the automatic gate could read, as well as the date and time of the reservation written in a large font so the ranger patrolling the parking lots can see they are at the summit for their proper reservation time. Reservations would ideally be linked to pass identification numbers, ensuring fee compliance for every car with a reservation by requiring them to have a pass valid for their reservation time. However, the park currently has a variety of pass vendors and may not receive information regarding which passes have been sold for several days (Miller-Rushing, 2017). A centralized pass system, able to track which passes have been sold in real-time, could inform the website to confirm pass number legitimacy. 100% fee compliance is an integral part of the effectiveness portion of the analysis.

A ranger should be stationed on top of Cadillac Mountain to enforce reservation times and inform visitors that they would need to leave the mountain to make room for those with reservations. In addition, another ranger would be placed at the base of the mountain to monitor the automatic gates and be available in the event of a technical malfunction or visitor confusion.

In order to test out the reservation system and allow visitors to grow accustomed to it, a phase-in plan would be required. In the proposed phase-in plan, sunrise would be implemented first using four-hour time blocks spanning the entirety of the peak time, with advance advertising to ensure as many visitors as possible learn about the reservation system before it begins. Sunrise was deemed the best peak time to test the reservation system due to the low number of visitors elsewhere in the park, creating less risk for the park as various aspects of the reservation system are tested and altered. Research would need to be done to monitor where the traffic diverted from the mountain would go, and if it would create other congestion issues elsewhere in the park. In addition, there would be fewer people on the mountain before the reservation period started compared to other times, leading to a smaller number of people for the park ranger atop Cadillac Mountain to ask to leave. This would allow the park to determine how effective this measure is for keeping visitors without reservations off the mountain during reservation-only times, and potentially implement another solution if the park ranger is not effective.

After piloting the reservation system at sunrise, an outcome assessment should be performed by the park, possibly at the end of the peak season for which it was implemented, to evaluate whether the reservation system was effective, spanning categories such as environmental impact, traffic congestion, and visitor safety and opinion. If it was deemed effective, the reservation system would be expanded to include sunset reservations, with the same four-hour block as the sunrise reservations. The impact of a reservation system at this time would again have to be monitored, as the effect of diverted traffic may have a more significant impact within the sunset hours, when there are more visitors in the park than at sunrise. Similarly, the potential for visitors to be on Cadillac Mountain's summit prior to the reservation time is increased, creating a greater need for effective management of visitors without reservations on the mountain. If the outcome assessment was still favorable, a plan for midday could be implemented. Due to the many complexities of midday reservations not present in sunrise and sunset reservations, including varying visitor dwell times, more research on the feasibility of reservations in the other peak times would be necessary before a proper investigation of how to implement reservations during midday could be performed. Midday reservations are discussed further in the following section, Future Recommendations.

Future Recommendations

The following subsections are ideas from conducting this project that could be valuable for future Worcester Polytechnic Institute teams and Acadia National Park to research further. Although the team believes it has determined the most feasible option for implementing a reservation system, the future has the ability to expand the reservations further, to both midday reservations and other areas of the park, and with it increase the technology supporting it with a centralized online system and intelligent transportation systems.

Midday Reservations

If midday reservations are to be implemented, there are several challenges not present in sunrise or sunset reservations. First, midday reservations would likely be consecutive, with no time between reservations. This means the methods Acadia National Park uses to enforce reservation times and ensure only visitors with valid reservations are allowed on the mountain would have to be effective and fully developed. Additionally, reservation systems during midday would need to account for a higher variability in visitor patterns; a reservation spanning four entire hours would not be effective, as most visitors only dwell at the summit for under an hour. Sunrise and sunset reservations have less variability in visitor times, as the visitors leave within half an hour of viewing the sunrise or sunset. Throughout midday, however, visitors are arriving and leaving at varying times and are not there to observe one event occurring at an exact time. In order to assess what sort of reservation system would be able to account for this continuous visitor traffic, all other elements of the reservation system would need to be known. Since the reservation system has not been implemented and may ultimately differ from what the team has recommended as various options are tested, it is difficult to determine the most effective solution for midday. However, the team recommends investigating a variable-length reservation system as discussed in the Cost-Effectiveness Analysis, as this would be able to account for different visitor plans atop the mountain, ranging from brief sightseeing to several-hour hikes.

Ocean Drive

As tourist numbers continue to increase, and a reservation system at Cadillac Mountain forces visitors into other areas of the park, more areas will become overcrowded. One of the most congested areas of the park already is the Ocean Drive portion of Park Loop Road. The survey provided to visitors investigated visitor opinion of making Ocean Drive a pedestrian-only drive. 56% of people supported it, with 18% strongly supporting it. Eventually, a reservation system may have to be put into effect on the Ocean Drive portion. It is recommended this system be connected to the system for Cadillac Mountain, and give the option for visitors to reserve for either, or both, of the locations at the same time. Ideally, all of the passes and reservations for the park would be run through a single centralized service.

Centralized Online Pass and Reservation System

Acadia National Park does not currently have a pass system which is guaranteed to update which passes have been sold and which have not. In some situations, the park does not receive updates on which passes have been sold for several days (Miller-Rushing, 2017). Creating a centralized online system for selling passes and reservations could solve several issues preventing additional automation, including real-time information on when passes and reservations are sold. A real-time comprehensive system, including all vendors, would be needed in order to provide multiple options for purchasing reservations without causing unintentional overbooking. However, such a system would make it easier for fee compliance to be enforced when making a reservation.

ITS Reservation Sign

This system would entail placing a sign at the base of Cadillac Mountain displaying real-time parking information, including numbers of available parking spaces and unsold reservation spots. This solution would notify visitors at the base of the mountain if there is space available, directing them away from Cadillac Mountain to either the proper location to purchase a reservation or other areas of the park. It could potentially allow visitors to retain a similar sense of spontaneity and freedom which contributed to their overwhelming aversion towards reservations in the data collected by the team. The sign would need communication to the online system to determine the amount of reservations available, electricity to power the sign, and sensors to determine the available parking spaces at the summit. The sign would be most effective if visitors were able to make same-day reservations as well as driving up the mountain freely when the lot was not fully booked.

Summary

The team believes it is feasible for Acadia National Park to implement a reservation system. The recommended solution involves two automatic gate lanes to handle the volume of the traffic up the summit and an independently run website to link park passes to reservations for guaranteed fee compliance. The team recommends phasing the system in over time, starting with only sunrise and then expanding to include sunset reservations, as it allows visitors to adapt to the system and the park to adjust the system as necessary. There are many improvements to be investigated for the future, including ITS signs for increased knowledge of visitors, a centralized pass system to track which passes have reservations linked to them more effectively, and expanding reservations to midday on Cadillac Mountain and potentially throughout other areas of the park. This team believes its recommendations will prove informative and useful for Acadia National Park as well as future Worcester Polytechnic Institute teams for years to come.

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Appendices

Appendix A: Survey Questions for Visitors with Consent Statement

Hello, we are students from Worcester Polytechnic Institute collecting information to assist Acadia National Park in improving visitor experience in its most popular tourist destinations. By taking this voluntary survey, you consent to providing general research information for Acadia National Park.

1. How many times have you been to Cadillac Mountain?
    a. 1 or less
    b. 2 to 3
    c. 4 or more

2. Would you prefer to…
    a. Drive up Cadillac Mountain at any time, but potentially be unable to get a parking spot
    b. Ensure a parking spot through a reservation, but only be able to go up Cadillac Mountain during your reservation time

3. If you needed to make a reservation to drive up Cadillac Mountain, how long would you want the time slot to last, in hours?
    a. 1
    b. 2
    c. 3
    d. 4
    e. More than 4. Please specify: _______

4. If you needed a reservation to drive up Cadillac Mountain, how much would you be willing to pay for it? __________

5. What is your preferred method of making a reservation (circle all that apply)?
    a. Call-in
    b. Kiosks throughout the park
    c. Mobile app
    d. Online
    e. Visitor Center
    f. Other: ___________

6. How would you feel about having the Ocean Drive portion of the Park Loop Road (encompassing Sand Beach and Thunder Hole) designated as a 'pedestrians only, no cars' road during peak hours of the day?
    a. Strongly support
    b. Support
    c. Don’t support
    d. Strongly disagree

Appendix B: Interview Questions for Staff

Consent Form:

Participation Form and Statement of Rights

We are students at Worcester Polytechnic Institute in Worcester, Massachusetts. We are conducting research on behalf of Acadia National Park to determine the effectiveness of a potential reservation system and gated parking lots. As part of this project we are conducting a series of interviews with key individuals. We have asked you to participate because we believe you have unique knowledge of these issues that will be valuable to the project.

Before we begin, we would like to thank you for taking the time to participate in the interview which will last about 10-20 minutes. Your participation is entirely voluntary. You may refuse to discuss any question or terminate the interview at any time. With your permission we would like to record the interview. In addition we would like to identify you by your age, gender and role within the park. The tapes, notes and subsequent transcripts of the interview will be kept confidential and will be accessible only by the members of the team and our immediate faculty advisors. Your name will not be used in subsequent report or publication without your permission.

If your consent to be interviewed at this time, we would ask that you indicate your agreement below.

I agree to participate in the interview ______________________ __________

Interviewee Signature Date

____

Interviewee Name

Please initial for permission to record ______________________

Interviewee Initials

______________________ __________

Interviewer Signature Date

Questions:

1. From your experience what has been the worst instance of parking/traffic congestion during your time here?
    a. What caused it?
    b. What time of day?
    c. Did the park staff take any initiative in mitigating it?
2. Is there a reason why park staff refrains from ticketing visitors on the sides of the road for not having a pass?

   a. Do you think fee compliance is an integral part of the parks daily function?
   b. What are some ways you can encourage visitors to pay the fees for the park
3. Why haven't solutions been implemented yet… what is the delay?
4. Do you think unmanned gated parking would be a better solution than automatic gated parking?
   a. Why?
   b. Do you think the park would have enough resources (staff, funds) to hire someone to work each gate?
5. How feasible would it be for park visitors to use technology while at the park
   a. What kinds of technology already exist around the park?
6. Have you heard of other parks implementing reservation systems at their most popular destinations during peak times?
   a. Do you think these reservation types of systems could be implemented here at Acadia?
   b. Where in the park would they work?
7. What recommendations do you have for us in terms of pursuing certain aspects of our project?
8. Do you have any other questions for us or anything you'd like to add?

Appendix C: Parking Length Observation Form

Date: ________ Day of Week: ___________ Parking Lot: _________________

Car ID Info	Time of Arrival	Time of Departure	Time Spent in Lot	Fee Compliant?
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				

Appendix D: Gated Lot Feasibility Form

Parking Lot/Location	Number of Entries/Exits	Natural Obstacles?	Size*	Additional Notes
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

*Measured by the approximate number of cars that can fit in lot

Appendix E: Comparison of Gated Parking Solutions

	Passive Management	Manned Parking Lots	Self-Pay Devices	Payment Stations	RFID-Operated Gates	Ticket-Operated Gates
Implementation Cost						
Operational Cost						
Maintenance Cost						
Public Opinion						
Ease of Use						
Successful Examples						
Unsuccessful Examples						
Timeframe for Implementation						
Expected Lifetime						

Appendix F: General Reservation System Concerns

Average Time Spent on Mountain	
Non-Reservation Accessibility	
Fairness of Access to the System	

Appendix G: Comparison of Reservation Platforms

	Recreation.gov	Friends of Acadia	Develop New Site
Cost			
Ease of Implementation			
Ease of Use			
Timeframe to Implementation			
Public Opinion			

Appendix H: Comparison of Reservation Enforcement Strategies

	Manned Gates	Automated Gates	Ticketing
Cost			
Ease of Implementation			
Timeframe to Implementation			
Public Opinion			

Appendix I: Cost-Effectiveness Analysis Form

Possible Improvements	Effects	Effectiveness Rank	Costs	Costs Rank	Cost-Effectiveness Ratio	Improvement Rank
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						

Appendix J: Visitor Survey Results

Visitor Center:

Frequency	Scenario	Reservation Length	Willing to Pay	Preferred Method					Pedestrian Only Ocean Drive
1	A	2	15	Call In		Mobile App	Online		Support
1	B	2	20				Online		Support
4+	A	2	5				Online	Visitor Center	Support
4+	A	2	5				Online		Strongly Support
2-3	A	2	20	Call In					Support
1	A	2	10			Mobile App			Support
1	B	3	5			Mobile App	Online		Support
1	B	2	5	Call In	Kiosks throughout the park	Mobile App	Online	Visitor Center	Support
1	A	4	10			Mobile App	Online	Visitor Center	Don't Support
1	B	2	10	Call In	Kiosks throughout the park	Mobile App	Online	Visitor Center	Strongly Support
1	B	2	7.5			Mobile App			Strongly Support
1	A	4	20			Mobile App			Support
1	A	3	7			Mobile App	Online	Visitor Center	Support
1	A	2	15	Call In		Mobile App	Online		Don't Support
1	A	1	15			Mobile App	Online		Strongly Support
1	A	1	20			Mobile App			Support
1	B	1	10				Online		Support
1	A	1	5		Kiosks throughout the park				Strongly Support
1	A	3	15	Call In		Mobile App	Online	Visitor Center	Support
1	B	2	5				Online	Visitor Center	Don't Support
1	A	2	5			Mobile App	Online		Support
1	A	3	0		Kiosks throughout the park				Don't Support
1	A	1	5				Online		Don't Support
1	A	2	5	Call In		Mobile App			Strongly Disagree
1	B	1	2			Mobile App			Support
1	A	2	10			Mobile App			Don't Support

Cadillac Mountain, Midday:

Frequency	Scenario	Reservation Length	Willing to Pay	Preferred Method						Pedestrian Only Ocean Drive	
1	*	1	0			Mobile App				Strongly Support	*"Bus"
1	A	1	0			Mobile App	Online			Don't Support	
4+	B*	1	5						**	Strongly Support	*"At peak" **Didn't circle any
1	A	1	0	Call In						Strongly Disagree	
2-3	B	3	10				Online			Support	
4+	A	2	0	Call In				Visitor Center		Don't Support	
2-3	B	2	10				Online			Strongly Support	
4+	A	1	0			Mobile App				Don't Support*	*"1 lane pedestrian + 1 lane cars"
4+	A	2	5-10	Call In		Mobile App		Visitor Center		Don't Support	
2-3	*	2	3			Mobile App				Don't Support	*"Some reserved + some 1st come 1st serve"
4+	A	1	0						No.	Don't Support	
4+	B	2	5					Visitor Center		Strongly Support	
1	A	1	5	Call In						Strongly Support	
1	A	3	0		Kiosks throughout the park					Support	
4+	A	1	5		Kiosks throughout the park	Mobile App	Online			Don't Support	
4+	A	1	5		Kiosks throughout the park	Mobile App	Online	Visitor Center		Don't Support	
2-3	A+B*	1	5			Mobile App	Online			Strongly Disagree	*"Some spots should be through reservation and should [not] be"
2-3	A*	2	15			Mobile App	Online	Visitor Center		Don't Support	*"with the knowledge that it's full"
1	A	1	10			Mobile App				Support	
1	B	2	10				Online			Don't Support	
2-3	A	*	0			Mobile App		Visitor Center		Strongly Disagree	*"I do not support reservations"
4+	A	2	0			Mobile App				Don't Support	
2-3	A	2	5	Call In						Don't Support*	*"Handicapped Accessible"
4+	A	2	0				Online	Visior Center		Strongly Disagree	
4+	A	2	0						None*	Strongly Disagree	*"More hadicap parking" (circled for emphasis)
2-3	A	1	10				Online			Support	

Cadillac Mountain, Sunset:

Frequency	Scenario	Reservation Length	Willing to Pay	Preferred Method						Pedestrian Only Ocean Drive	
1	A	2	10		Kiosks throughout the park		Online	Visitor Center		Support	
1	A	1	10	Call-in		Mobile App				Strongly Support	
2-3	B	2	5			Mobile App	Online			Support	
2-3	A	2	0		Kiosks throughout the park					Strongly Disagree	
2-3	A	6	10				Online			Strongly Support	
1	A	2	15		Kiosks throughout the park	Mobile App	Online	Visitor Center		Support	
2-3	A	4	4*	Call-in			Online			Don't Support	*"$1 per hr"
1	B	3	0			Mobile App	Online			Support	
1	A	3	10				Online			Support	
1	B	1	*	Call-in						Strongly Disagree	*No Response
1	B	2	5	Call-in				Visitor Center		Strongly Support	
1	A	4	5				Online			Support	
4+	B	*	50				Online			Strongly Support	*"Varying--As requested"
4+	A	1	10	Call-in						Support	
4	A	2	0				Online			Strongly Disagree	
1	A	4	20	Call-In						Don't Support	
1	A	2	7.5			Mobile App				Don't Support	
1	A	1	10				Online			Support	
1	B	2	5				Online			Strongly Support	
1	A	3	15				Online			Support	
4+	A	1	20	Call-in		Mobile App	Online	Visitor Center		Support	
2-3	A	1	20	Call-in	Kiosks Throughout the Park		Online	Visitor Center		Don't Support	
2-3	A	3	25				Online			Strongly Support	
4+	A	1	10				Online			Strongly Support	
4+	B	2	7				Online			Strongly Support	
2-3	A	1	10		Kiosks Throughout the Park					Support	

Cadillac Mountain, Sunrise:

Frequency	Scenario	Reservation Length	Willing to Pay	Preferred Method					Pedestrian Only Ocean Drive	
2-3	A	3	0	Call-In				Visitor Center	Strongly Disagree	
1	A	2	10				Online		Don't Support	
1	A	1	0	Call-In					Support	
1	B	2	0			Mobile App			Don't Support	
1	A	2	10	Call-In	Kiosks Throughout the Park	Mobile App	Online	Visitor Center	Support	
1	A	1	10			Mobile App	Online	Visitor Center	Don't Support	
2-3	A	2	5	Call-In			Online	Visitor Center	Support	
2-3	B	2	*	Call-In					Don't Support	*"Yes"
2-3	A	1	0				Online		Don't Support	
1	A	2	10				Online		Don't Support	
2-3	A	3	*				Online		Support	
4+	A	*	0	**					**	*"Should be variable" ** No opinion
2-3	A	2	5	Call-In					Support	
1	A	1	0				Online		**	** No opinion
2-3	A	2	0	Call-In					Strongly Support	
1	A	2	20			Mobile App		Visitor Center	Support	
2-3	B	2	2		Kiosks throughout the park	Mobile App	Online	Visitor Center	Strongly Disagree	
1	A	1	1	Call-In		Mobile App		Visitor Center	Strongly Disagree	
1	A	1	1			Mobile App			Don't Support	
1	A	1	0	*					Strongly Disagree	*"Do not support"
2-3	A	2	20	Call-In	Kiosks Throughout the Park	Mobile App	Online		Don't Support	
1	B	2	5			Mobile App	Online		Support	
1	A	2	10		Kiosks Throughout the Park	Mobile App	Online		Support	
1	A	4	20	Call-In	Kiosks Throughout the Park	Mobile App	Online	Visitor Center	Support	
4+	B	2	*				Online		Support	*"?"
4+	B	1	3			Mobile App	Online		Strongly Disagree	