Traffic Mobility Patterns on the Ocean Drive Corridor

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Abstract

In recent years vehicle congestion has become a problem in Acadia National Park. The Ocean Drive Corridor is one area of the park where congestion is a major problem. Our project collects data through the use of Streetlight, in-person monitoring, camera monitoring and questionnaires. We found that visitors do not stay in the Sand Beach Area very long, the majority of people do not visit Sand Beach, visitors are willing to use a reservation system and the Island Explorer is an option for transportation in the Ocean Drive Corridor. Our recommendations for Acadia are the implementation of a new pilot reservation system specifically at the Sand Beach Parking Lot and increasing advertisement of the Island Explorer.

Traffic Mobility Patterns on the Ocean Drive Corridor

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Executive Summary

In recent years traffic and congestion have been an increasing issue around the world. In the United States, National Parks are locations where overcrowding has become a significant issue. Acadia National Park, one of the smallest National Parks, is greatly affected by overcrowding. This overcrowding is focused around many popular locations, including around the Sand Beach Parking Lot area. Acadia intends to reduce the traffic in this area, with a reservation system.

Figure Executive

Sand Beach

This project was intended to provide Acadia with additional data on the movements of visitors in the Ocean Drive Corridor, specifically the trends of vehicles around Sand Beach. The collected data can then be used to choose the best method to reduce traffic congestion in the Ocean Drive Corridor. This was accomplished through two objectives:

1. Identify trends in the current traffic at Sand Beach and Ocean Drive Corridor
2. Explore and determine trends in the opinions and experiences of Sand Beach visitors on traffic congestion and possible alternatives

Our data collection methods revolved around three strategies;

1. On-the-ground data collection
2. Digital data collection
3. Public response measurement.

On-the-ground traffic data was collected through the use of trail cameras and in-person monitoring. Trail cameras were placed at seven locations in the Sand Beach Parking Lot to monitor when visitors arrive and leave. In-person monitoring collected the same data for cars parked along the right-hand side of Park Loop Road.

Digital data was collected through Streetlight, a web-based data collection and analysis service for traffic. Streetlight collects data using cell phones as sensors, then uses a machine learning algorithm to analyze the data. The program was used to determine patterns in visitor arrival, departure, and destination.

Public response was measured through the use of questionnaires. These questionnaires obtained data on visitors' destinations and preferences on possible traffic solutions or alternatives.

From these methods, we had four significant findings:

1. Most people entering the Ocean Drive Corridor don't go to Sand Beach
2. People parking at Sand Beach leave quickly and are constantly arriving
3. People are willing to use a reservation system
4. The Island Explorer is a viable option for those visiting the Ocean Drive Corridor.

The first finding was derived from Streetlight data and questionnaire responses. Our analyses showed that 52% of visitors that pass through the entrance station do not stop at any point along the Ocean Drive Corridor. Those visitors either exit at Otter Cliff Road or continue further along Park Loop Road. Furthermore, of the people that park in the Sand Beach Parking Lot, the majority do not visit Sand Beach. This data showed that only between 27-31% of visitors parking in the Sand Beach Parking Lot visit Sand Beach, and that 65-69% of visitors go hiking. This indicates people stop in the Sand Beach Parking Lot more for hiking than for Sand Beach.

The second finding was derived from Streetlight data and our on-the-ground methods. Our camera analysis showed that, of the visitors parking in the Sand Beach Parking Lot, 28% don't stay longer than 30 minutes, and 69% do not stay longer than two hours. The in-person monitoring data had similar trends, with 18% staying up to 30 minutes and 52% staying up to two hours. This shows that the majority of visitors are not staying very long. As for parking arrival, Streetlight data corroborated both our camera and in-person monitoring data. Parking at the Sand Beach Parking Lot has a peak arrival between 8:00 a.m. and 9:00 a.m, with consistent parking arrivals until between 3:00 p.m. and 4:00 p.m. Right-hand parking has peak arrival times between 10:00 a.m. and 11:00 a.m, and is consistent through 3:00 p.m. This suggests that Right-hand parking does not begin in earnest until the Sand Beach Parking Lot is near or at capacity.

The third finding was found through questionnaire responses. Of the 524 visitors who responded, 80% of visitors would be willing to use a reservation system. Of those who were unwilling, 32% said it was because they didn't think Sand Beach was worth the inconvenience. Another 32% said they thought a reservation system would be unfair or restrictive to visitors who want to visit. These two points made up the majority of objections to a reservation system.

Additionally, we found that of those willing to use a reservation system, 44% would be willing to pay five or six dollars for a reservation. While not the majority, it was by far the most common answer. This finding shows that the public has a majority positive reception to a reservation system.

The fourth finding was derived through questionnaire responses as well. We found that of the 524 visitors who responded, 48% were uninformed of the Island Explorer Shuttle Service.

However, once they were informed, we found that 72% of all respondents were willing to use the Island Explorer in place of their cars to travel the park. Of those who were unwilling, 52% said they desired more freedom or independence with their schedule while visiting the park. Another 22% said they would rather use their cars or would use other alternative modes of transportation. This data shows that the majority of visitors at Sand Beach would be willing to rely on currently existing public transportation options instead of using their own cars.

From these findings we have the following two recommendations for Acadia National Park:

1. A second pilot reservation system with key differences from the original pilot test
2. Increased advertisement of the Island Explorer Shuttle System

Our first recommendation is for Acadia National Park to conduct a new pilot reservation system with a few key differences between this and the 2020 pilot test. The first major difference is the location where the reservations should be checked. We recommend checking the reservations in the entranceway for the Sand Beach Parking Lot specifically. This allows the 52% of cars that just pass through the Ocean Drive Corridor to do so without needing to make a reservation, and it guarantees that the reservations are for parking spots at the Sand Beach. The following key difference is that the reservations should be for two-hour time blocks. The blocks should start at 6 a.m. and end at 8 p.m. Based on the 44% of people willing to pay five or six dollars for a reservation, we recommend that the reservations cost six dollars each.

Our second recommendation to the park is to increase the advertisement of the Island Explorer Shuttle Service. We found that 72% of visitors are willing to use the shuttle system, but 48% of visitors don't know about it. By increasing the number of visitors that know about the shuttle system, the number of visitors using the shuttle system should also increase. More visitors using the shuttle system could help relieve the traffic congestion in the Ocean Drive Corridor.

In addition to recommendations for Acadia, we have created four recommendations for future research by WPI. The recommendations are:

1. Island Explorer Study
2. Economic Impact Study of Closing the Park Loop Road to Private Vehicles
3. Similar Studies at other Popular Locations
4. Communication Study

The goal of the Island Explorer Study would be to determine if the Island Explorer Shuttle System is working efficiently and if it can be improved. This study would be useful to the park because public transportation can be the solution to Acadia's traffic issues.

The goal of the economic impact of closing the Park Loop Road study would be to determine how the closing of the road to personal vehicles would financially affect the park and the businesses of Bar Harbor. This will allow Acadia to see if this is a viable option to eliminate traffic within the park since it is an option in their transportation plan.

The goal of the similar studies study would have the same goals as this project. The project would just be focused at other locations like Jordan Pond House, Sieur de Monts/ Nature Center, or the Bass Harbor Lighthouse.

The goals of a communication study would be to determine if Acadia is doing a satisfactory job of communicating with visitors. This will help Acadia learn the best ways to communicate with visitors and spread important information.

Acknowledgments

The Ocean Drive Corridor Team would like to acknowledge several individuals who helped to guide our project to completion. We would like to start by thanking our WPI advisors Professor Bianchi and Professor Kurlanska, who helped to guide us through our work with comments and recommendations to better our research. The team would also like to acknowledge the parks Science Coordinator Abe Miller-Rushing and Management Assistant John Kelly for their knowledge and information provided about Acadia National Park. Lastly we would like to thank all park personnel who assisted in our research and for allowing us to conduct research at Acadia National Park.

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1.0 Introduction

In the United States, National Parks were created to protect the environment and preserve nature for future generations. Traffic and congestion threaten these objectives. In recent years, there has been a dramatic increase in the number of people visiting National Parks which has led to overcrowding. From 2010 to 2019, the National Park Service (NPS) recorded an increase from around 281 million to over 327 million total visitors respectively across over 400 national parks (*Stats Report Viewer*, n.d.). This shows a 16.1% increase in visits over a nine-year span. The overcrowding in the parks is responsible for increased traffic which increases pollution in the parks as well as affecting the visitor experience.

One park experiencing overcrowding is Acadia National Park, located in Maine. Many visitors travel throughout the park by car along the scenic Park Loop Road, creating traffic. One area responsible for the traffic congestion is the Ocean Drive Corridor. Acadia National Park has attempted to fix the traffic issue at the Ocean Drive Corridor in the past, but was unsuccessful. Our main goal was to understand the challenges of parking at Sand Beach and provide possible solutions to the park. Chapter 2 focuses on the background research we conducted to achieve our first goal. Topics include traffic congestion's negative global impacts and solutions for global traffic issues. Chapter 3 outlines what methods we used to collect data to further our understanding. These methods include camera and in-person monitoring and the use of questionnaires. This data was collected and analyzed for trends and findings on topics such as visitors' destination and duration of stay Chapter Four. The findings were then used to produce recommendations for alleviating traffic issues near Sand Beach in Chapter 5.

2.0 Background

2.1 Global Traffic and Congestion

Anyone who has driven has been a part of traffic, and most have experienced traffic congestion. By definition, traffic is "the movement (as of vehicles or pedestrians) through an area or along a route" (Merriam-Webster, 2021). Traffic congestion is when traffic is reduced below its free flow value, but some sources define it as when the current traffic flow is half of the free flow value (Arnott, 1994). However, traffic is often used interchangeably with traffic congestion.

Traffic congestion affects drivers around the world. One group of drivers that are frequently affected by traffic are commuters. Since these drivers are going to the same location everyday they may take different routes to avoid traffic or they may take the one they are most comfortable with whether or not traffic is present. This may cause the driver to take a longer route or route with more traffic than necessary (Klugl, 2004). This thought process is similar to people on vacation. It is common that people driving to a vacation destination would choose the longer route if it is more scenic (Alivand et al., 2014). Scenic roads are not immune to traffic. Congestion on these roads can negatively impact the experience of the visitors using them. On scenic roads congestion is determined by the number of cars a driver can see driving in front of them (Hallo & Manning, 2009). Traffic congestion's impediment on vacation and leisure time driving should not be understated.

A common reaction to traffic congestion is an increase in aggression or anger. This response is often brought on by several irritating acts that can worsen visitor experience. These irritating acts can include, but are not limited to, illegal pedestrian crossing, aberrant overtaking by other cars, and preceding cars driving slowly (Wu et al., 2018). These phenomena are common in any place with high traffic. Predicted increases in annual visitor entrance could develop or increase these phenomena and traffic congestion along these popular roads (Bergstrom et al., 2020). Increased occurrence of these irritating acts leads to more driver aggression (Wu et al., 2018). This leads to further diminished visitor experience in what should be a relaxing leisure drive.

Traffic congestion is also known to lead to air pollution (Spark, 2018). Air pollution is known to release aromatic hydrocarbons which degrade the Earth's ozone layer (Perraudin et al., 2006). This is a global issue that negatively affects everyone. Air pollution is also shown to stunt the growth and quality of nearby vegetation (Honour et al., 2009). This is especially harmful to areas where health and visual quality of nearby flora is an important aspect of day-to-day life. Air pollution from traffic also has detrimental effects on physical health, such as respiratory problems, particularly in young children (Nordling et al., 2008). Areas where traffic congestion is more common may exasperate these issues.

One main factor of air pollution is idling cars (Carrico et al., 2009.). The three main reasons for leaving a car idle are to warm the engine, wait for a passenger, or being stuck in traffic (Carrico et al., 2009). Two of these reasons can easily be prevented but idling in traffic requires more work. It would be dangerous to turn a car off and on while in stopped traffic so the best way to eliminate this type of idling is by reducing traffic (Carrico et al., 2009).

2.2 Global Traffic Solutions

2.2.1 Mass Transportation

One method many locations have adopted to reduce traffic is the increased use of mass transportation. This allows for more people to travel throughout cities, parks, and other popular areas in shorter periods. Common forms of mass transportation can include buses and shuttles (APTAAdmin, n.d.). Mass transportation can be implemented at both micro and macro levels. Micro-scale areas such as sports stadiums in the United States use shuttles to move visitors to their stadiums (Steinbach, 2014). Macro-scale countries like the Philippines have implemented a nationwide bus system called Bus Rapid Transit (BRT) to achieve a similar effect (Boquet, 2019). Both micro and macro implementations of mass transportation have the same goal: to provide accessible transportation for people while reducing traffic congestion in their respective areas.

2.2.2 Increasing Cost and Parking Tickets

Another traffic reduction method is increasing the cost of parking and tickets to encourage the use of public transportation. This can be done by increasing the cost of hourly parking and strictly enforcing parking rules though fines. Studies have been done to test this theory in Thessaloniki, Greece and Beijing, China (Morfoulaki, 2017), (Li, W, 2008). Both locations found that more people were willing to use public transportation to avoid the cost of parking. The increased number of people using public transportation in these areas has led to less traffic congestion.

2.2.3 Reservation Systems

Another method for reducing traffic congestion is the use of a reservation system. This system can be applied to individual parking spots, parking lots, or entire highways. Research shows that 40 percent of traffic in cities comes from vehicles trying to find a parking spot (Noor et al., 2017). Reservation systems used in cities apply to these high-demand parking spots to alleviate congestion (Noor et al., 2017). Popular National Parks in the United States use parking spot or parking lot reservation systems to decrease traffic congestion and maintain order as well(Parking and Shuttle Reservations, 2017, *Yosemite National Park*, 2017, *Haleakala National Park*, 2021). The implementation of a reservation system for an entire highway has been researched in South Korea, with positive public reception as a finding (Kim & Kang, 2011). Their widespread use is due to their effect on high-traffic areas. Reservation systems can decrease traffic by reducing the demand while also allowing those with reservations to arrive at their destinations on time (Kurauchi, 2008). This makes them a competitive solution for resolving traffic issues.

2.3 National Park Solutions

2.3.1 National Parks

Since 1872, 63 National Parks have been established in the United States and more continue to be added each year (National Parks Foundation,n.d.). National Parks are protected historical or scenic places in the country. The National Park Service (NPS) was created to protect and preserve the natural and cultural resources of the parks to ensure people of current and future generations can enjoy and learn from these locations (National Park Service & U.S. Department of the Interior, 2016, p.2). To help accomplish these goals, the National Parks Service has a four-part action plan.

Figure 2.1

National Park Goals Chart (*A Call*, 2016, p. [Page 8-22])

National Park Action Plan Goals
1. Connect People to Parks 2. Advance the National Park Service's Education Mission 3. Preserve America's Special Places 4. Enhance Professional and Organizational Excellence

Goal one is to connect people to the parks. This is accomplished by teaching the importance of National Parks "through a continuum of engaging recreational, educational, volunteer, and work experience"(*A Call*, 2016, p. [Page 12]). Goal two of the plan creates opportunities for students to experience and learn from the parks to foster appreciation. Updates to virtual content and increasing learning opportunities contribute to this goal. Goal three works to preserve the parks by reducing pollution. This increases spending on more frequented areas of the park to protect and improve them. Goal four aims to improve park personnel's structural organization to accelerate the spread of ideas, encourage collaboration, and inspire innovation (*A Call*, 2016, p. [Page 8-22]). This action plan preserves Natural Parks to introduce them to new generations.

The goal of reducing areas of pollution in the parks is the most relevant to our project. One source of pollution in the parks comes from cars. Cars are the leading mode of transportation through larger National Parks which also leads to traffic (Youngs, 2006). In the United States idling cars account for "93 MMt of CO2 and 10.6 billion gallons of gasoline" (Carrico et al., 2009/n.d., p.). Reducing traffic, and the number of idle cars, will result in less pollution.

Another goal of the National Park Service is to create a good visitor experience to encourage people to visit National Parks. One area that affects visitor experience in a National Park is transportation. Many visitors enjoy the freedom of having their own vehicles to travel around the park even though this adds to the issue of overcrowding and traffic (Youngs, 2006). National Parks like Denali, Great Smoky Mountains, and Acadia have invested in the use of other modes of transportation for visitors to experience the park like shuttle systems. Parks that implement these systems have found mixed results. For example, some visitors of the Great Smoky Mountains National Park opposed the system because they felt it takes away their freedom (Youngs, 2006). The freedom to drive oneself is especially important to visitors who feel driving for pleasure on scenic roads is a part of the National Park experience (Hallo & Manning, 2009). Even in daily life people have been known to go out of their way in order to take a scenic route (Alivand et al., 2014). In Acadia the Ocean Drive Corridor is one of these scenic routes. The visitor experience on this stretch of road is affected by the number of cars in the driver's line of sight (Hallo & Manning, 2009). One way to increase visitor experience is by reducing traffic within the parks.

2.3.2 Visitors and Occupancy

Other National Parks struggle with overcrowding and traffic congestion. To make visits more enjoyable they have created ways to manage congestion. One method is a reservation system that regulates traffic flow. For example, Yosemite National Park, Muir Woods National Monument, and Haleakala National Park have all created successful reservation systems. After comparing these systems certain policies stand out.

2.3.3 Muir Woods Reservation System

Muir Woods National Monument in California has seen a drastic 30 percent increase in visitors between 2006 and 2016 (National Parks Service, 2017). To decrease crowding and traffic congestion a reservation system was created. Reservations for both parking and shuttles are required for all guests. Shuttles pick up visitors from the parking lot and bring them to the entrance of the monument. Visitors are able to make a reservation ninety days in advance. Same-day reservations are also available. There is an eight-dollar car reservation fee and a three-dollar shuttle fee for visitors older than sixteen (Parking and Shuttle Reservations, 2017). Visitors will be emailed a unique barcode as their pass which they must either download or print prior to arrival (*Park Reports Success at Muir Woods*, 2019). Some locals are not happy with the implementation, saying that they have not been involved with the process (Braden Cartwright, 2019) However, the reservation system limiting access to the park has been deemed a success, allowing more people to enjoy Muir Woods (David Flynn, 2020).

2.3.4 Yosemite Reservation System

Yosemite National Park also experiences overcrowding and traffic congestion. A reservation system was implemented to correct these issues. The current reservation system requires visitors to make a thirty-five-dollar reservation prior to arriving at the park (*Yosemite National Park*, 2017). Visitors must show proof of reservation and matching ID before entering. Prior to the Covid-19 Pandemic, these reservations were valid for seven consecutive days of unlimited entrance (*Entrance Reservations*, 2021). Currently, the passes are valid for three consecutive days. If spending the night, the pass will last for the duration of stay (National Park Service, 2021). This allowed more passes to be sold and more visitors to experience Yosemite National park during the pandemic.

2.3.5 Haleakalā Reservation System

Haleakalā National Park is a popular place to see the sunrise on the island of Maui, Hawaii. This popularity led to a parking reservation system during sunrise hours. Reservations can be made 60 days in advance with a $1 reservation fee (*Haleakala National Park*, 2021). The park entrance fee is separate and paid on the day of the visit. The Sunrise reservation allows visitors to enter between 3:00 a.m. and 7:00 a.m. on the reserved day. Visitors must display the printed reservation on their dashboard and present a matching photo ID to enter. Once visitors enter the park, they will be directed to one of four parking lots. Parking in a specific lot is not guaranteed, and spots are first come first serve (National Park Service, 2021).

2.3.6 Reservation System Comparisons

The systems at Muir Woods National Monument, Yosemite National Park, Haleakalā National Park serve as models for other national parks (*Park Reports Success at Muir Woods*,

2019)(*Yosemite National Park*, 2017)(*Haleakala National Park*, 2021). The chart below shows each system's features.

Figure 2.2

Reservation System Comparison Chart

	Models		
	Muir Woods	Yosemite	Haleakalā
Cost of reservation	8$	35$	1$
Earliest availability (days)	90	7	60
Shuttle availability	Yes (3$)	Yes (free)	No
Proof of reservation	Barcode	Proof of reservation and matching ID	Printed proof of reservation and matching ID

2.4 Acadia National Park

Maine has a National Park on its coast: Acadia National Park. Car travel is the leading mode of transportation around the park due to the convenience of an extensive road network. The core of this network is Park Loop Road, a 27-mile road that wraps around eastern Acadia (*Park Loop Road - Acadia National Park*, n.d.). Park Loop Road is a busy road, and therefore easily congested. The congestion can cause pollution and negatively affects visitors which contradicts the National Park Services third goal (*A Call*, 2016, p.8-22). Visitors have other options to move around the park including shuttle, foot and bike. The Island Explorer Shuttle service also transports visitors throughout the park. Shuttles visit locations every 30 minutes (Route 3, 2021). Approximately six-hundred-thousand visitors use this shuttle system each year ('Nightmare' Sand, n.d.).

Figure 2.3

Map of Park Loop Road

In 2020, Acadia was the 8th most visited National Park in the country (*Visitation Numbers*, 2021). The park received more than 2 million visitors. The majority of these visits occurred in a four-month span between July and October ("Stats Report Viewer", 2021). Records indicate August had the highest average number of cars entering the park per month over the last ten years at 72,189 vehicles. From 2017 to 2019, the park received an average of 753,000 visitors in July, 760,000 in August, and 600,000 in September ("Stats Report Viewer", 2021). Within those same years, Yellowstone National Park received on average 946,000 visitors in July, 850,000 visitors in August, and 686,000 in September ("Stats Report Viewer", 2021). Yellowstone National Park has a net area of 2.22 million acres as compared to Acadia's 49,075 acres. During its busiest months, Acadia receives between 79% and 89% of Yellowstone's visitors while occupying 2.25% of its area. The data shows that Acadia has higher visitor densities than other National Parks. These visitor densities lead Acadia to have congestion issues.

2.5 Acadia Traffic Alternatives

2.5.1 Plans of Action

Due to increased traffic and visitor displeasure, Acadia began developing the Final Transportation Plan/Environmental Impact Statement (Acadia National Park Final Transportation Plan Environmental Impact Statement, 2019). This document outlines alternatives to reduce traffic. Acadia stated, "These alternatives are designed as three distinctly different approaches that address how and when visitors would access different popular destinations in the park" (Acadia National Park Final Transportation Plan Environmental Impact Statement, 2019).

Figure 2.4

Transportation Plan Breakdown

Alternative Plans of Action	
Alternative A: No Actions	This plan requires no action, the park will continue to operate as it normally does.
Alternative B: Site Management	The park would manage the number of cars on Ocean Drive, possibly by a reservation system during peak season, as well as eliminating parking along the Park Loop Road and increasing the use of the Island Explorer.
Alternative C: Corridor Management	The Park would create two entrances to the park for peak times while all other existing entrances would be exits as well as creating a reservation system for Park Loop Road and Cadillac Mountain during peak hours.
Alternative D: Park Loop Road Management	The park would require visitors to use public transportation during the peak season on Park Loop Road and during the shoulder seasons private vehicles will be allowed but the number allowed will be controlled.

The implementation of reservation systems are included in Alternatives B-D (Acadia National Park Final Transportation Plan Environmental Impact Statement, 2019). A reservation system has been successfully implemented at Cadillac Mountain. The park currently lacks the visitor behavior and traffic mobility information needed for a reservation system in other areas.

2.5.2 Cadillac Mountain Reservation System

The Cadillac Mountain Summit is a popular location in Acadia. It is the highest point along the North Atlantic seaboard, and the first place in the United States to see the sunrise between October and March (Hartford, n.d.). People travel from across the country to see this

sunrise. Most visitors drive their cars to the top of the mountain (National Park Service, n.d.). Cadillac’s popularity often causes crowding during the park's peak season. A reservation system has been put in place to control traffic, and to allow visitors easier access.

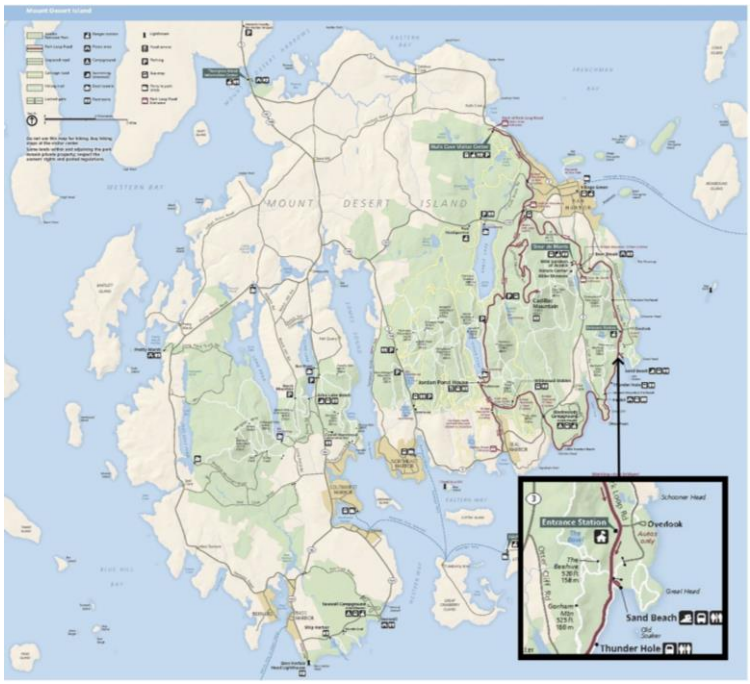
Figure 2.5

Sunrise From Top of Cadillac Mountain

Currently, only Cadillac Mountain has a parking reservation system. Reservations at Cadillac Mountain only occur during the peak season. (National Park Service, n.d.). Thirty percent of the spots are available ninety days beforehand. The remaining spots become available two days before. The reservations are split into two times: sunrise and daytime (*Acadia National Park*, 2021). These dictate entry time, but not departure time. People can reserve one daytime spot per day. However, visitors can only make one sunrise reservation per week. All reservations have a six-dollar fee and give the user a QR code for confirmation (*Acadia National Park Vehicle Reservations*). Before entering the Summit road, visitors must download or print proof of reservation. Individual spots are first come first serve.

Figure 2.6

Map of Acadia With Marker at Sand Beach



2.6 Sand Beach

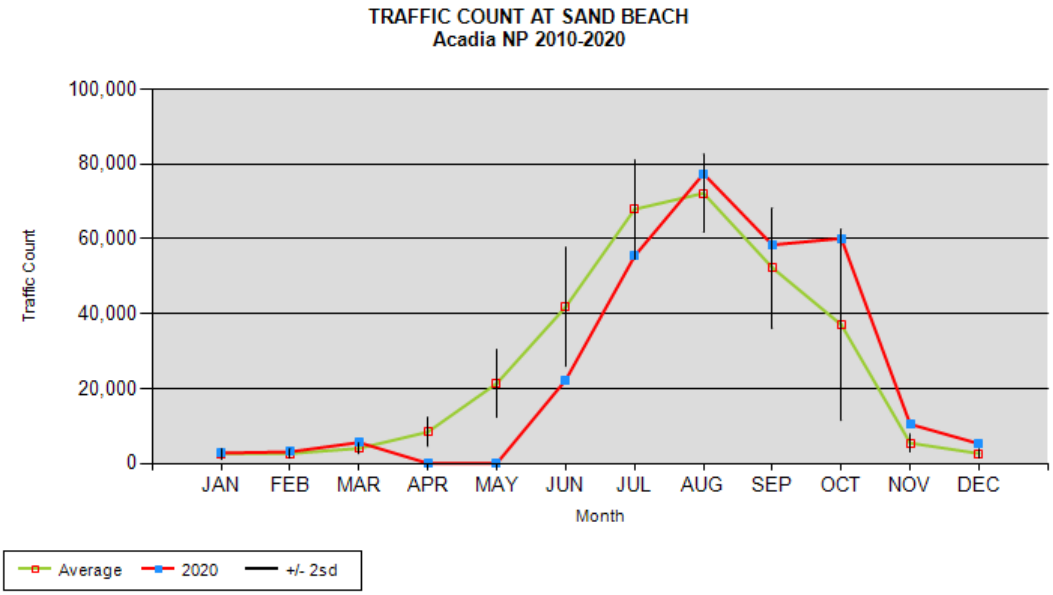
2.6.1 Sand Beach

Sand Beach, located off the Ocean Drive Corridor of Park Loop Road, stretches 290 yards along the eastern side of Mount Desert Island (Hartford, G.A., n.d.). Visitors are permitted to swim in the frigid water or relax on the beach. Visitors also have access to public restrooms and changing rooms near the parking lot. From the parking lot there are also three trailheads nearby.

Sand Beach's popularity leads to congestion in its parking lot and the surrounding road. The Sand Beach Parking Lot offers free parking with 101 parking spaces including handicap accessible spots. The parking lot stays open for 24 hours, but the busiest times occur between the hours of 8 a.m. and 4 p.m. (*Parking*, 2020). On average, the parking spaces at Sand Beach will fill up by 9 a.m., according to (NPS) reports (*Parking*, 2020). The Final Transportation Plan presented by Acadia National Park states visitors have permission to park in the right lane of Park Loop Road. The right lane often gets filled up during the peak season (July-August) when the Ocean Drive Corridor parking lots reach capacity (Acadia National Park Final Transportation Plan Environmental Impact Statement, 2019).

Figure 2.7

Average Sand Beach Traffic Over the Last Ten Years (NPS, 2020)



2.6.2 Pilot Reservation System at Sand Beach

In October of 2020 Acadia ran a two-week pilot test of their reservation system at Cadillac Mountain and the Ocean Drive Corridor. The test was successful at Cadillac Mountain but a nightmare all along the Ocean Drive Corridor, specifically at Sand Beach (*'Nightmare' Sand*, n.d.). During the test period, a reservation was required to enter the Ocean Drive Corridor from 7 a.m. to 5 p.m., but the reservation had no exit time (Schreiber, 2020). Reservations had to be made online in advance of arrival. Visitors were required to show proof of reservation to park at both Sand Beach and Cadillac Mountain (Schreiber, 2020).

The first issue with the Ocean Drive Corridor Reservation System was that people did not know a reservation was required. Acadia tried to spread the word that a reservation was needed through posts made on their social media pages, and rack cards distributed to nearby hotels and visitor centers. These methods were insufficient, and many people arrived without a reservation (Schreiber, 2020). If a visitor arrived with no reservation, they were not permitted to enter and directed down the Schooner Head Road. This usually calm residential road became impassable with the traffic from the park. Inhabitants of the road were concerned by the gridlock and speeding of the redirected traffic (*'Nightmare' Sand*, n.d.).

One main issue with the Ocean Drive Corridor Reservation System was the method of showing the reservation. Many visitors were unable to show their reservations when they arrived at the Ocean Drive Corridor. The reservation system gave visitors the option to display their reservations on their cell phones. Unfortunately, cell reception at the entrance to the Ocean Drive Corridor is almost unusable. This prevented visitors from showing proof of reservation causing them to be turned away.The visitors who were turned away took the same route as those with no reservation, adding to the traffic on Schooner Head Road (*'Nightmare' Sand*, n.d.). This

observation from the pilot test shows that Acadia National Park needs to ensure reservations can be easily shown at the Sand Beach entrance.

3.0 Methods

Our project goal was to understand the challenges and restrictions of parking at Sand Beach and provide recommendations on how to alleviate traffic issues. We did this through the completion of our two objectives:

1. Identify trends in the current traffic at Sand Beach and Ocean Drive Corridor
2. Explore and determine trends in the opinions and experiences of Sand Beach visitors on traffic congestion and possible alternatives

3.1 Identify Trends in the Current Traffic

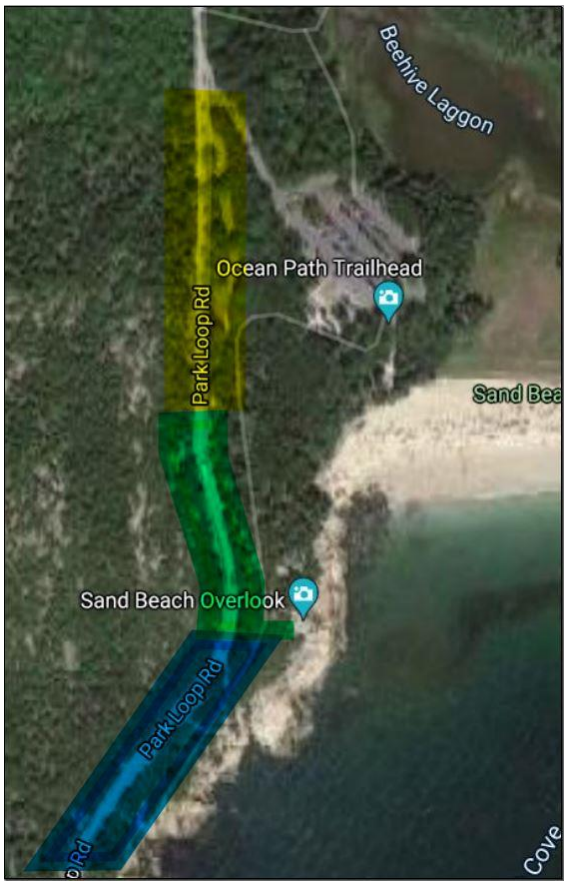
The first objective was to identify trends in the traffic and parking in and around the Sand Beach Parking Lot. We identified trends in the traffic through the collection and analysis of traffic data.These trends were turnover rate, times of full capacity, and reason for parking. Three data collection methods were used to gain a comprehensive understanding of Sand Beach's traffic: In-person monitoring, Camera monitoring, and Streetlight *Insight®*. This data will help provide Acadia with useful recommendations.

3.1.1 In-person Monitoring

In-person monitoring was used to collect data on the length of stay of cars parking on the road outside the Sand Beach Parking Lot. This was done in eight hour shifts over the course of five weeks. During this time, over 1500 cars were monitored. These shifts began as early as 6 a.m. and went as late as 7 p.m. Three team members were stationed along the road to monitor zones which consisted of 10-20 cars each. These zones are shown below in Figure 3.1. The entry and exit times of the cars were recorded. Using these times we calculated the duration of the car's stay. All data collected was placed into a spreadsheet. Here we counted the total number of data points entered, tallied the total number of entrances and departures by time of arrival, and calculated the durations of stay by time of arrival. These values were then converted to percentages relative to the total.

Figure 3.1

Road Monitoring Zones

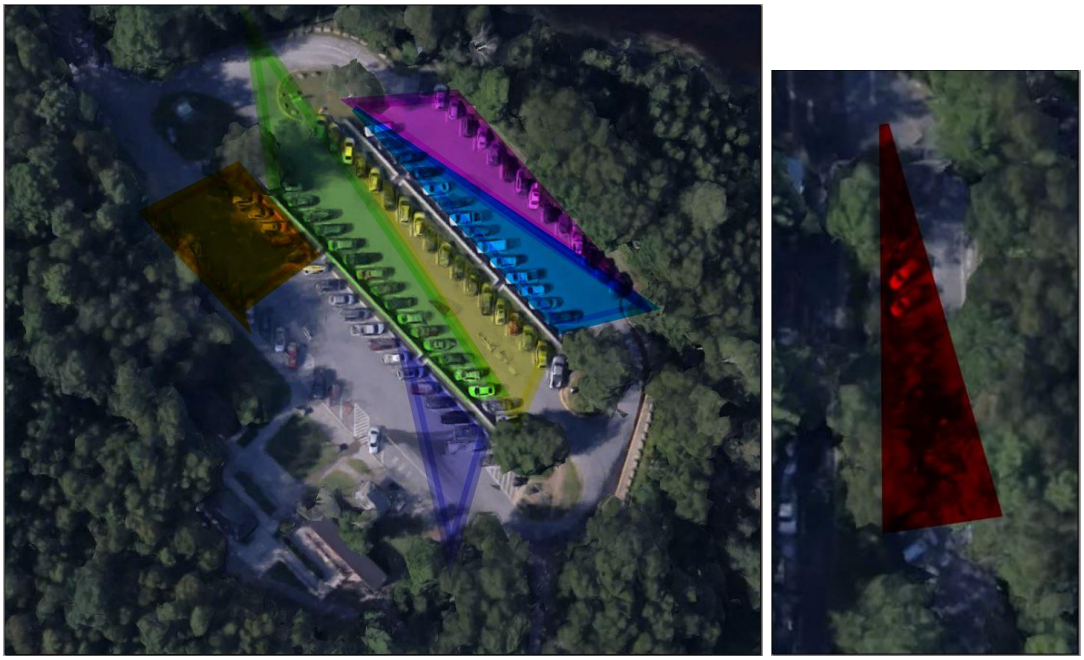


3.1.2 Camera Monitoring

Additionally, we placed seven cameras in the Sand Beach Parking Lot and secondary lot. The six main lot cameras were placed so that each row had two cameras observing it. Each one was pointing towards opposite sides of the row. Their positions are shown in Figures 3.2 and 3.3. All of the cameras were set on Time-lapse, taking pictures at set intervals of one minute. These cameras were used continuously for a five week period. In total, over 132,000 pictures were taken allowing us to determine the duration of stay for about 6700 cars. The pictures were analyzed by seeing when cars entered and exited specific parking lots. All of the data collected was placed into a spreadsheet where the aforementioned methods were applied.

Figure 3.2 and 3.3

Sand Beach Parking Lot Camera Coverage and Sand Beach Auxiliary Lot Camera Coverage



3.1.3 Streetlight Analysis

Our third method used to collect data was Streetlight. Streetlight is a data analysis tool that uses data collected from GPS location on phones to determine trends in traffic behavior. In Streetlight, the user can create a polygon zone or line gate. Polygon zones monitor the cars that pass through and stay in the zone. Line gates monitor cars that pass through specialized zones (For more information see Appendix C). To collect information, we began by setting up a series of zones and gates. The zones corresponded with the parking lots that we monitored through cameras. The gates were set up along the road sections that we believed were relevant. Relevance was determined by proximity to Sand Beach. We created approximately twenty zones, spanning about two and a half miles, for analysis. These road sections in particular stretched between the entrance station and the end of the last monitored lot. These zones and road segment gates allowed us to conduct a series of Streetlight analyses.

We primarily used Modular and Segment analysis. Modular analysis was conducted in our parking lot zones. The modular analysis gave us information on the activity within the parking lot zone and the origin-destination information. The activity information was our primary focus. It provided us with duration of stay, time of day, and trip length. Segment analysis was conducted on our road segment gates. Using this, we collected similar information to the modular analysis, but for road segments. Some of the most important information collected was the duration visitors were parked and times of day the lot was full. Streetlight does not use real time data so the trends that were found are from 2018 through 2020. The data collected through Streetlight was used to provide Acadia with information regarding traffic patterns around Sand Beach.

3.2 Identify Trends in Opinions and Experiences

The second objective was to identify trends in visitors' opinions and experiences on traffic congestion and possible alternatives. We focused on those parked in and around the Sand Beach lot. The information needed to identify trends in opinions and experiences was obtained through questionnaires (Williams, 2003)). These questionnaires were administered using the Brew Survey app. Responses were coded for patterns and common themes. These patterns and themes will help Acadia develop a viable traffic solution.

3.2.1 Sand Beach Questionnaires

Qualitative data on visitor opinions at Sand Beach was gathered through questionnaires. These questionnaires allowed us to record participants' responses for our multiple-choice and free-response questions. We were interested in five main topics:

1. The current traffic at Sand Beach
2. Experience with the functioning Cadillac Mountain reservation system
3. A possible Sand Beach reservation system
4. Alternative transportation methods
5. Acadia's communication with visitors

The third topic was especially important as it pertains to the fourth alternative of the Transportation plan that would eliminate personal vehicles in the park. Some questions that were included in the questionnaire are as follows:

- Did traffic affect your arrival time to Sand Beach?
- Do you think a reservation system would help reduce traffic at Sand Beach?
- Are you aware of the Island Explorer shuttle system?

The full questionnaire for visitors parking at Sand Beach can be seen in Appendix B. We were able to collect 524 questionnaires in our time we were giving them out. The collected free-responses were coded to determine visitor reception to the Island Explorer and Cadillac Mountain Reservation System (Williams, 2003). The questionnaires were administered by team members in the Sand Beach parking Lot.

3.2.2 Questionnaire Response Coding and Analysis

After the questionnaires were conducted, we coded the free-responses. Coding is the process by which questionnaire responses are labeled, organized, and analyzed (Williams, 2003). The responses were exported from Brew Survey into Microsoft Excel. This allowed each set of responses to be viewed in an organized grid. Next the responses were categorized and tallied. From there, we determined the most and least common responses for important metrics. These metrics included but were not limited to: opinions on current Sand Beach Traffic, purpose for visiting the Sand Beach rest area, and awareness and willingness to use the Island Explorer Shuttle. This information advises Acadia on how visitors currently view traffic and reservation systems and informs them on how visitors would like to see certain problems be resolved or solutions implemented.

4.0 Results and Discussion

In this section we will present and discuss our results. This includes data gathered through in-person and camera monitoring, streetlight and questionnaires. It should be noted that due to time constraints with in-person monitoring, we chose not to record certain data points. This will cause some of our related Right-hand parking data not to equal a total 100%. We have found trends in visitor destinations in the Ocean Drive Corridor, duration of stay around Sand Beach and visitor opinions of the Island Explorer.

4.1 Most People Entering the Ocean Drive Corridor Aren't Going to Sand Beach

Our first key finding is that people entering the Ocean Drive Corridor tend to not go to Sand Beach. The information for this finding was gathered using monitoring, streetlight, and questionnaires. These methods showed us that more than half of people do not stop while going through the Ocean Drive Corridor, and the majority of those that do stop do not visit Sand Beach.

4.1.1 Where Do People Go

The first component of our finding mentioned above is that the majority of people entering the Ocean Drive Corridor do not stop. This data was obtained through Streetlight and is displayed below in Figure 4.1.

Figure 4.1

Vehicle First Destination at Ocean Drive Corridor Distribution

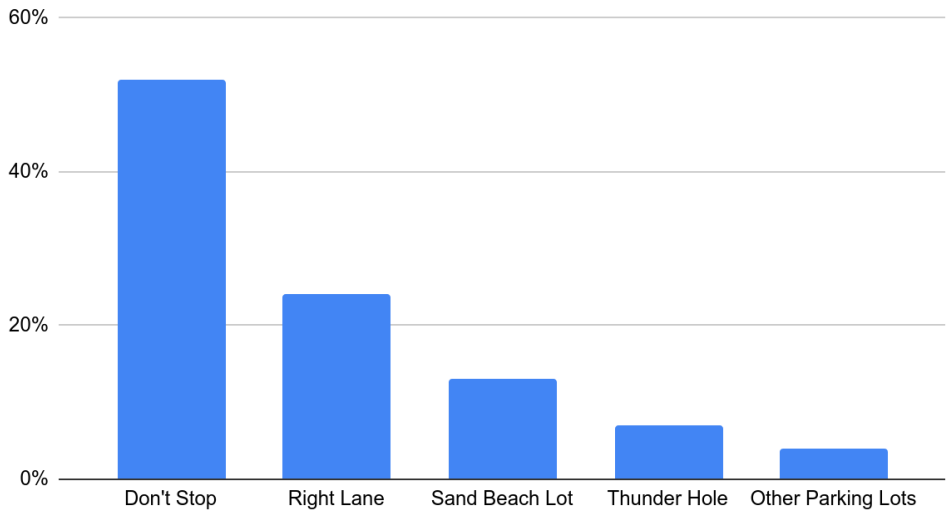


Figure 4.1 shows that 52% of visitors continue along the Ocean Drive Corridor without stopping. The data collected here has a massive implication; over a third of people that enter the Ocean Drive Corridor do not park at all. We were also able to determine the percentage of cars that stay on the Park Loop Road after making one stop in the Ocean Drive Corridor. Streetlight Data shows that 70% of cars turn off of the Park Loop Road at the Otter Cliff Exit. This matches the on-the-ground data we briefly collected. Our on-the-ground data produced 71% of people who remained on the Park Loop road, the rest turned off. We have also found that 94% of people

leave the Park Loop Road after parking at the Sand Beach Lot with only a small 3% of people parking again at Thunder Hole.

A factor that impacts whether a reservation system will work is visitor destination. Understanding visitors' destination after they park can help Acadia mold a reservation system to their movements. We collected data on this using Streetlight and questionnaires. The results are shown in Figures 4.2 and 4.3.

Figure 4.2

Streetlight Analysis of Visitor Destination From Sand Beach Parking Lot

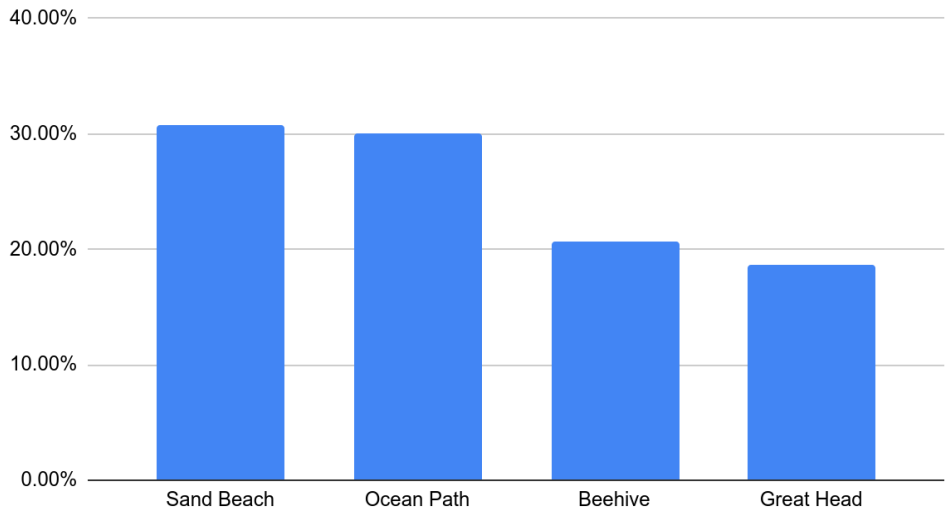
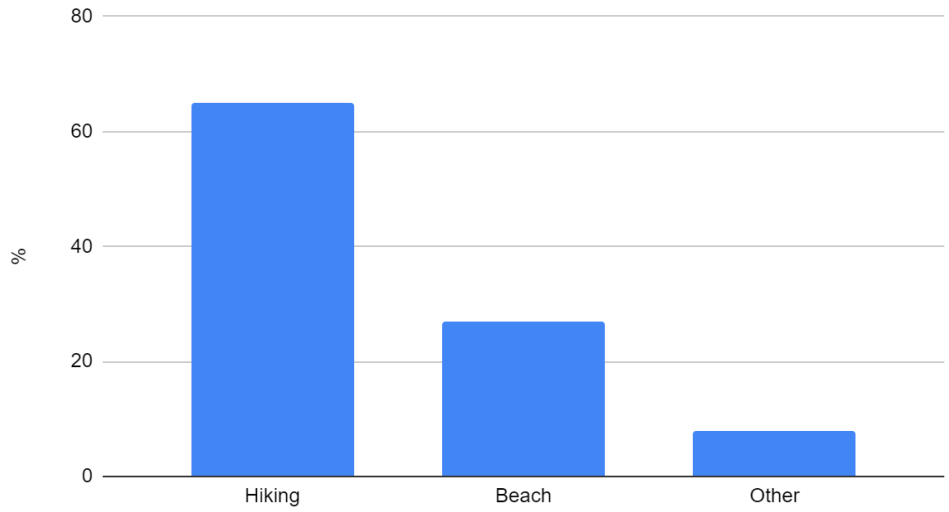


Figure 4.3

Questionnaire Results of Visitor Destination From Sand Beach Parking Lot



The hard data presented by Figure 4.2 shows that only 31% of visitors that park at the Sand Beach Lot actually visit the beach. Instead they tend to go hiking on the surrounding trails like Ocean Path, Great Head, and Beehive. The data in Figure 4.3 corroborates the Streetlight analysis with in-situ data. Through questionnaires we found that out of the 524 visitors questioned, 65% were going hiking, while only 27% were going to Sand Beach. Both of these results corroborate the finding that most people entering the Ocean Drive Corridor aren't visiting Sand Beach.

4.2 Sand Beach Visitors Arrive Constantly and Leave Quickly

Our second key finding is that visitors parking near Sand Beach do not park for very long. Our assumption was that people parking in the area were staying for long periods, causing traffic to back up into the road and the Right-lane parking to fill up for over a mile. According to the data collected, this is not the reason for these effects.

4.2.1 Durations of Stay

The basis for this finding comes from our camera and in-person monitoring data. These datasets revolved around three metrics. The first two were times of arrival and departure. These two times were then compared to find our third key metric: duration of stay. The following graphs depict the durations of stay for the Sand Beach Parking Lot and Right-hand parking.

Figure 4.4

Durations of stay for cars parked in the Sand Beach Lot

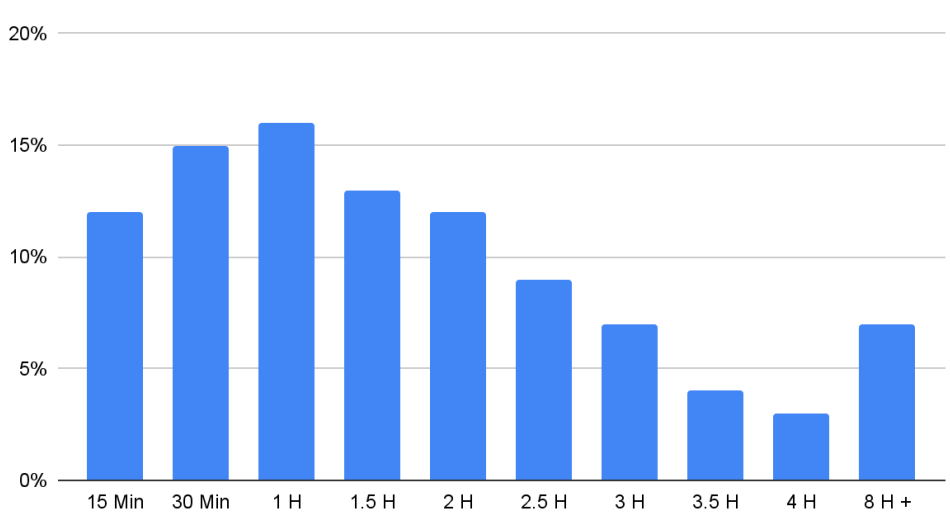
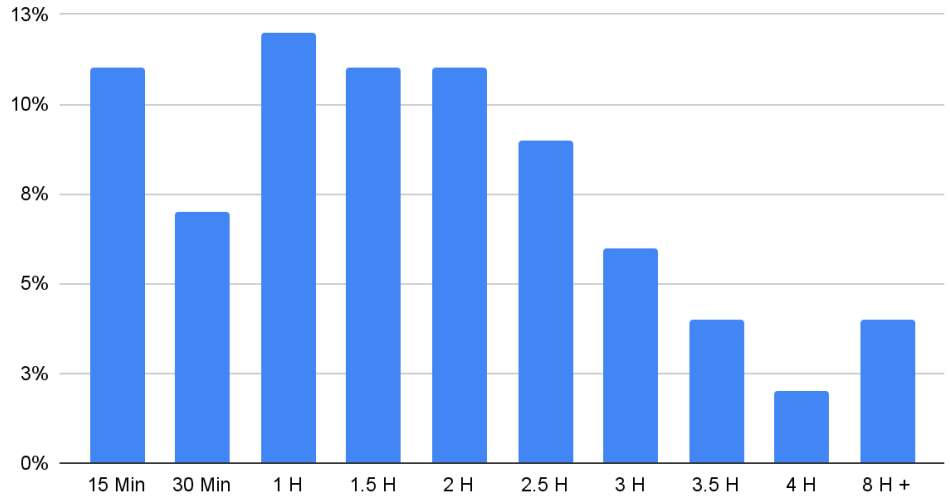


Figure 4.5

Durations of Stay for Cars in Right-Hand Parking



These sets of data are the primary basis for our finding. The Sand Beach Parking Lot data shows over 25% of vehicles do not park for longer than 30 minutes. Additionally, over 67% of vehicles in the lot stay for less than two hours. The Right-hand parking data shares this trend, but to a lesser extent. It shows that 19% of visitors park 30 minutes or less, and 54% park two hours or less. Combined this means that 22% of vehicles park for 30 minutes or less, and 60% of vehicles park for less than two hours.

4.2.2 Times of Arrival

Our second finding is further supported by our arrival time data. In addition to our monitoring methods, Streetlight was also used to derive these times of arrival for both the Sand Beach Lot and Right-hand parking. These datasets are shown comparatively below in Figures 4.6 and 4.7.

Figure 4.6

Arrival Times of Parked Cars in the Sand Beach Parking Lot

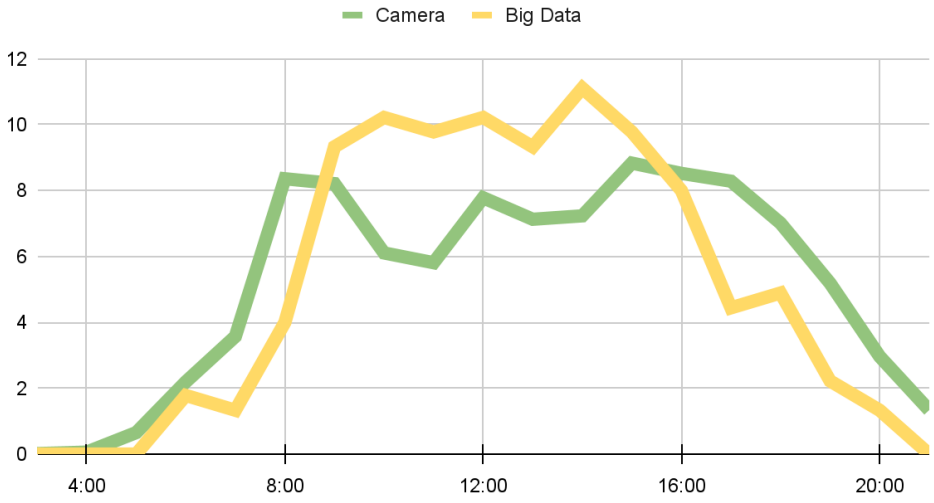
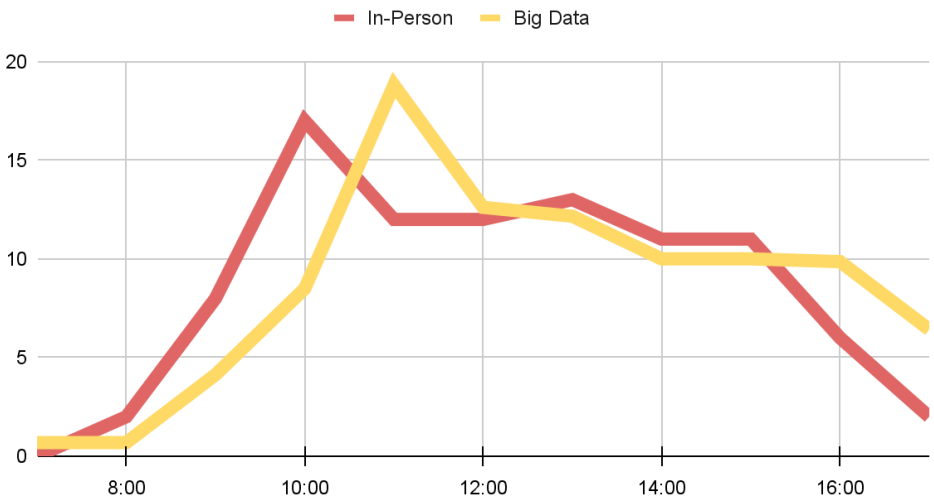


Figure 4.7

Arrival Times of Cars in Right-Hand Parking



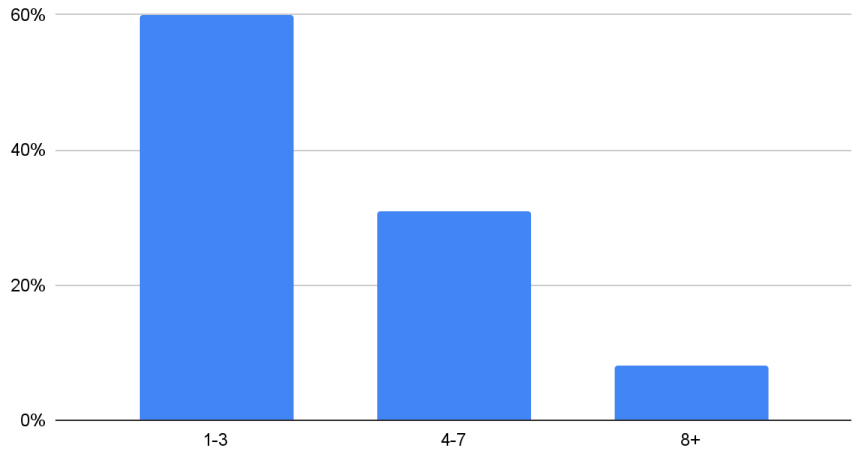
It is important to note that the key takeaways from these graphs are not the individual values but the overall trends of arrival. The Sand Beach data shows that visitors are continuously parking in the lot after 6 a.m. The Right-hand parking data shows a similar trend beginning at 9 a.m. Logically, the only way cars can be continuously arriving at these locations is if spots are becoming available at a similar rate. This data further suggests that visitors do not park very long.

4.2.3 Preferred Duration of Stay

The final piece of supporting data comes from our questionnaires. One of the questions we asked relating to a reservation system was how long visitors would park with a reservation. The breakdown of these responses is shown below in Figure 4.8.

Figure 4.8

Preferred Duration of Stay



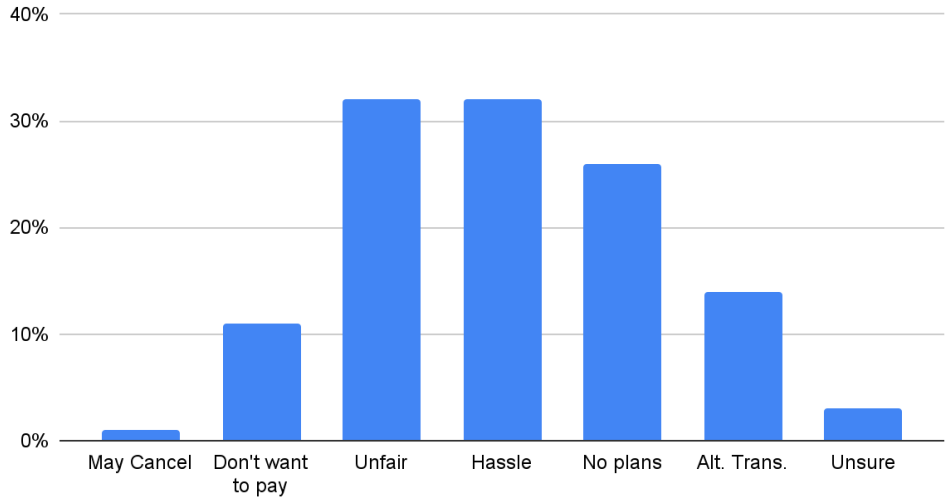
Our questionnaire data shows that 60% of visitors would make a reservation for between only one to three hours. This data further corroborates our finding that people parking near the Sand Beach Parking Lot do not stay for very long.

4.3 People Are Willing to Use a Reservation System

Our questionnaires also produced another finding: people are willing to use a reservation system. In addition to duration of stay, we also included questions regarding parking at the Sand Beach Parking Lot. The most important of these questions was whether they would be willing to make a reservation in order to park at the Sand Beach Parking Lot. Our response data showed that 80% of visitors would in fact be willing to make a reservation in order to park at Sand Beach. Of those who were unwilling, we asked why they wouldn't be willing to make a reservation. The two most popular answers were that they considered the process restrictive to visitors and that it wasn't worth it to park at Sand Beach. All of these responses are shown below in Figure 4.9.

Figure 4.9

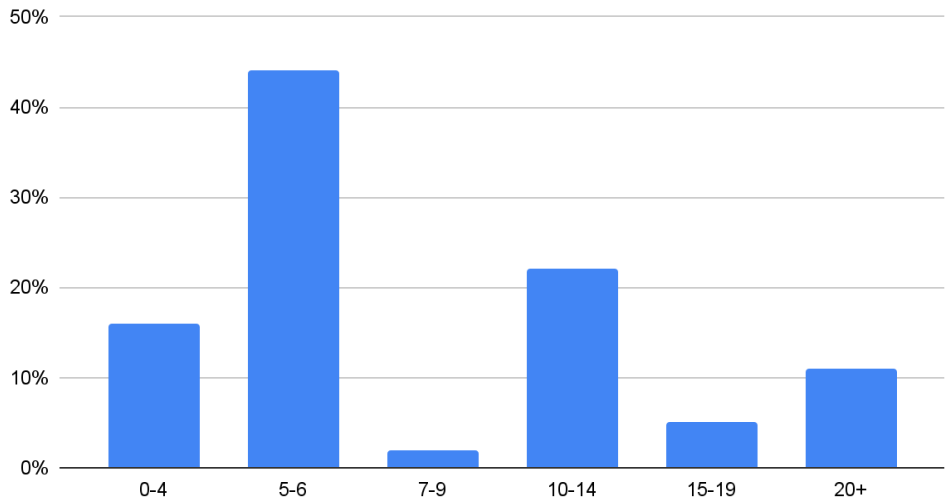
Visitors' Reasons Against a Sand Beach Reservation System



Another question regarding parking at Sand Beach was how much they thought a parking spot at the Sand Beach Parking Lot should cost. The results from this data are shown below in Figure 4.10.

Figure 4.10

Visitor Preferred Value of Parking



As shown above, we found that 44% of visitors would be willing to pay either five or six dollars in order to reserve a parking spot at the Sand Beach Parking Lot. The second highest response was 10 to 14 dollars at 22%. This suggests that most visitors would be most willing to pay a lower cost for parking near Sand Beach.

4.4 Island Explorer is a Viable Option for People Visiting the Ocean Drive Corridor

The Island Explorer is a mobility option that can greatly help the National Park. Data acquired through questionnaires shows that 42% of people were unaware of the Island Explorer. Meaning only a narrow majority were aware of the shuttle system. However, when asked if they were willing to use the Island Explorer instead of their own car, 72% of all responses said they were willing. Of the 28% of people that said they were not willing to use the Island explorer, 52% said it was because they wished to have independence while visiting the park. An additional 22% said it was because they had an alternative mode of transportation and 21% said no because they had pets with them. Acadia has already seen the fact that when people are aware of the Island Explorer more people use it, "In Acadia, an optional shuttle began operation in 1999, with ridership increasing by 75 % over a 2-year period as visitors became more aware of the free shuttle service."(Mace et al., 2013) Through the same research, it was found that overtime people become more receptive to Shuttle systems and the decrease of overcrowding it provides.

4.5 Discussion

Our main research objective was the feasibility of a reservation system at the Sand Beach Parking Lot. According to our questionnaire data, 80% of visitors would be willing to use such a system. This sets a precedent for the implementation of a pilot reservation system. The following sections of this chapter elaborate on our above findings and relate them to different components of such a reservation system.

4.5.1 Discussion of Visitor Destination

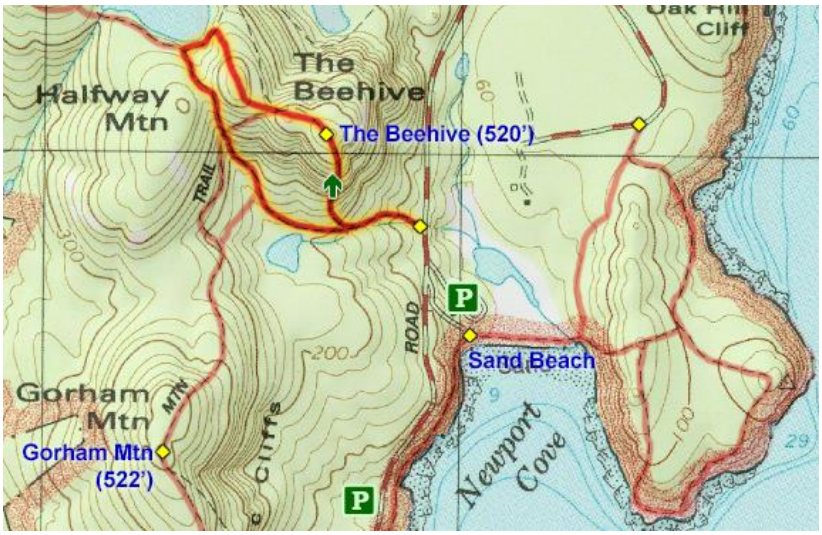
One of our key findings was that the majority of people parking at the Sand Beach Lot are there for hiking rather than Sand Beach. Most of the trails these hikers take can be accessed from other locations and parking lots seen in Figure 4.11. The unnecessary parking at the Sand Beach Parking Lot raises visitor density. High visitor density can make for an unpleasant visitor experience (Vistad & Vorkinn, 2012). A large amount of foot traffic occurs in the Sand Beach Lot and Ocean Drive Corridor. The issue of overcrowding stems from hikers parking near or in the Sand Beach Lot and using the same space as beach goers.This is where the overall experience for both beach users and hikers can diminish. On the trails hikers are free to pass others or slow down to let others pass them, essentially meaning hikers can go at their own pace. Unlike hikers, beach users are limited to the same area as other visitors for their stay on the beach. An ideal spot on a beach is away from other people, but with a small shared area and high visitor density the overall beach experience can go down quickly. In a study done in Telašćica park in Croatia both beach users and hikers were asked through questionnaires to rate how overcrowded the area was and how it affected them. Beach users were reporting both higher crowding and disturbance to the crowding than hikers (Klanjšček, 2018). This shows that, without a way to regulate people parking at the Sand Beach Parking Lot, beach-goers' experience may be negatively affected.

Another important finding was that the majority of people do not stop in the Ocean Drive Corridor. The Ocean Drive Corridor is one of the scenic roads in Acadia. Many visitors who come to this location come to experience the scenery through recreational driving (Hallo & Manning, 2009). From conversations with park personnel, we learned that people planning to just drive through the corridor didn't make parking reservations during the 2020 pilot test. Similarly, in Yosemite National Park visitors show up without a reservation and are allowed to drive directly through the park as long as they do not stop (*Entrance Reservations*, 2021). We

believe this is one of the reasons the pilot reservation system in 2020 inadvertently created more traffic congestion. The majority of drivers don't stop in the Ocean Drive Corridor and do not visit Sand Beach. It may still be seen as a major location, but it does not have as much traffic as one might expect. This may require a new approach to the region, making it more holistic than focusing just on the importance of Sand Beach.

Figure 4.11

Trail Map of Hikes Near Sand Beach



4.5.2 Discussion of Parking Turnover

Our duration of stay data also has significant implications. The majority of cars staying for two hours or less suggests that the Sand Beach Parking Lot and nearby Right-hand parking have high turnover rates. This would contribute to the traffic congestion along Park Loop Road. We believe that the constant flow of cars stopping to find, enter, or exit a spot along the road can create backups for drivers behind them. These backups can be expected since cars that park in the right hand lane are required to parallel park (Yousif & PhD, 1999). The action of parallel parking takes longer to complete than angled parking. Parallel parking also required the driver to block or reduce the driving area which can affect the ability of cars to pass. The blocking of the road can cause a bottleneck which increases traffic while the driver is parking (Yousif & PhD, 1999). Based on the high turnover rate of the right hand lane, this blockage of traffic happens frequently. Knowing the duration of stays helps understand the traffic and how to control it. The high turnover rate means that the traffic is caused by the large amounts of cars coming into the area every hour rather than because the parking spots are always filled. This means that to properly control the traffic problem the amount of visitors coming each hour could be controlled by evening out the spread or by directly limiting how many can come in (Acadia National Park Final Transportation Plan Environmental Impact Statement, 2019).

Controlling or restricting traffic in order to alleviate systemic stress can be done. Traffic restrictions can be used to reduce the number of cars during peak hours, decrease air pollution, and increase use of public transportation (Rivera, 2021). Restrictions can also make non-local visitors flexible in the routes they take or shift visitors away from problematic destinations

altogether (Gundersen et al., 2015). These traffic controls could take many forms, including traffic bans or reservation systems. These measures would help alleviate aforementioned problems related to high traffic, such as decreased visitor enjoyment, and air pollution. The applicability of each of these solutions depend on the circumstances, namely whether or not the public would be willing to comply and whether or not alternative transportation methods are available.

5.0 Recommendations

5.1 Park Recommendations

5.1.1 Pilot Reservation System 2.0

Our key recommendation for Acadia National Park is the implementation of a new pilot reservation system located only at the Sand Beach Parking Lot. Reservations should be checked at the Sand Beach Parking Lot Entrance instead of the Entrance Station. This would disrupt traffic on the Ocean Drive Corridor less. We also recommend the length of the reservations be in two hour time blocks, with both an entrance and exit time. Reservations would be required from 6 a.m. until 8 p.m. This would be different from the all day Cadillac Mountain Reservations and the previous pilot test reservations. This comes from our finding that 69% of visitors stay for two hours or less. Since 46% percent of people would be willing to pay between five and nine dollars, and the median is six dollars, we recommend the reservations cost six dollars.

5.1.2 Increased Island Explorer Advertisement

Our second recommendation we have is for the park to increase advertisement of the Island Explorer. We found that 42% of visitors are unaware of the Island Explorer, but 72% of all visitors were willing to use this service instead of their car. If visitors were made more aware of this free park service it could lead to fewer cars in the park resulting in less traffic congestion. Increased use of the Island Explorer would also aid any reservation system put in place.

5.2 WPI Recommendations

5.2.1 Island Explorer Study

We recommend that WPI does a future project focusing on the Island Explorer Shuttle System. We believe that public transportation could be the future for Acadia National Park's traffic solutions. However, for this to be the case, a study must be done to check the current viability of the Island Explorer to complete such an action. Research could be done in areas such as: amount of people in each bus, efficiency of current routes, or possible other routes.

5.2.2 Economic Impact Study of Closing the Park Loop Road to Private Vehicles

Our next recommendation for future WPI projects is the study of the economic impact of closing the Park Loop Road to private vehicles. This is based on one of the options in the Acadia National Park action plan, which suggests this exact thing. By studying the economic impact, future research could provide Acadia National Park with the information necessary to make educated steps in this direction. This study would span the economic impacts on Acadia National Park as well as local businesses, specifically during the summer tourist season.

5.2.3 Similar Studies at Other Popular Locations

Our research focused on traffic patterns and mobility analysis of the Ocean Drive Corridor, specifically focused around the Sand Beach Parking Lot. We are suggesting further studies to be done at other popular locations in the park. The next prominent location could be the Jordan Pond area as it receives a large percentage of the park's visitors. Other locations could be Bass Harbor Lighthouse, Sieur de Monts Spring/Nature Center, or Hulls Cove Visitor Center. These studies would focus on learning more about the traffic in the area and providing recommendations to the park on ways to help relieve traffic and parking problems.

5.2.4 Communication Study

The final recommendation of future study we are giving to WPI is for a study of the communication between Acadia National Park and its visitors. We are suggesting research be done on the best ways for Acadia National Park to communicate with visitors, and ways to improve the communication. This would cover announcements through the website and social media, but would also include communication of other information through maps and signs. Anecdotally we found people wanted better maps and signs for the park to help them navigate to the trails they wanted to go on. Further study would help determine the best ways for Acadia to improve its communication with visitors.

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Appendix A: History of Acadia National Park

President Woodrow Wilson established Acadia as a National Park in 1916 (Foundation Document, 2016). The first National Park east of the Mississippi River, Acadia's formation came entirely through private land donations to the public by conservationist citizens. Acadia currently resides on approximately 49,000 acres of land spread across several islands in an archipelago (Hartford, Park History, n.d.). The Park Loop Road, along with Acadia's carriage roads, was originally created in 1922 by George Dorr and paid for by John D. Rockefeller, Jr (Harbor & Us, n.d.). Dorr had a vision for a road system that connected Eagle Lake and Jordan Pond and would give access to Cadillac Mountain (Harbor & Us, n.d.). Rockefeller funded the road's construction, as well as added his own contribution to the park's road plans. Rockefeller planned for a single "Park Loop Road" that would provide visitors access to the island's varied landscapes (Harbor & Us, n.d.). Construction on the road began in 1927 (Harbor & Us, n.d.).The road was later expanded during the 1950s to incorporate motor networks. Park Loop Road now connects many of the most popular and visited sites in the park.

Appendix B: Visitor Questionnaire for Sand Beach

Sand Beach Questionnaire Goals

1. Opinion on current traffic situation
2. Purpose
3. Opinions on parking alternatives
    a. Buses v. Car parking
4. Opinions on Cadillac Mt. system
5. Opinions on Acadia's advertising capabilities/ favored communication methods

Speech Before Questions

Hello, I am a student from Worcester Polytechnic Institute, a college in Worcester, Massachuestts. My team and I are collecting information to help Acadia National Park manage traffic and review the success of their reservation systems . Would you be willing to participate in an anonymous questionnaire? You do not have to answer all questions and you can stop at any point. The questionnaire should only take around five minutes.

Would you like contact information for our team?

gr-barharborbeach@wpi.edu
cbkurlanska@wpi.edu
bianchi@wpi.edu

Sand Beach and Surrounding Area Questionnaire:

1. Have you been to Acadia within the last year prior to this visit?
    a. Yes
        i. Did you visit Sand Beach during the reservation system pilot test?
            1. Yes
                a. What was your experience with the reservation system?
                    i. Open text
            2. no
    b. No
2. What are you planning on doing in the area?
    a. Going Hiking
    b. Going to the Beach
    c. Other (free response)
3. Did traffic in Acadia along Park Loop Road delay your arrival time to Sand Beach?
    a. Yes
    b. No
4. Rate your experience of the traffic around the Sand Beach Area?
    a. 1 - 5 (Traffic was horrendous to Traffic wasn't an issue)
5. Are you informed of the Island Explorer Shuttle System?
    a. Yes
    b. No
6. Would you be willing to use the Island Explorer instead of your car to travel around the park?
    a. Yes
    b. No
        i. Why not? (Select all the apply)

1. Traveling with a family
2. Traveling with to much stuff
3. Shuttles are not frequent enough
4. Shuttle does not stop at all locations
5. Other (explain)

7. Are you aware of the reservation system for Cadillac Mountain?
    a. Yes
        i. Have you made a reservation for Cadillac mountain before?
            1. Yes.
                a. How would you rate the online reservation usability?
                    i. 1-5 (Scale)
                b. How would you rate the easability of finding a parking spot on Cadillac Mountain?
                    i. 1-5 (Scale)
            2. No.
    b. No
        i. It is a system where you can reserve a spot from a specific time for the rest of the day to park at Cadillac Mountain Parking Lot. Currently these reservations cost $6.
8. On a scale of 1-5, how much do you think a reservation system at Sand Beach would help with parking?
    a. 1-5 (Scale)
9. On a scale of 1-5, how much do you think a reservation system at Sand Beach would help with traffic congestion?
    a. 1-5 (Scale)
10. Would you be willing to make a reservation to visit Sand Beach?
    a. Yes
        i. How long would you prefer the reservation be?
            1. 1 to 3 hours
            2. 4 to 7 hours
            3. 8+ hours
        ii. How much would you be willing to pay for a parking spot [at Sand Beach]?
            1. Open ended
    b. No
        i. Why not?
            1. Open ended text
11. Does Acadia National Park do a satisfactory job of advertising important information with visitors?
    a. Yes
    b. No
        i. What method do you believe would be better for sharing information?
            1. Open ended text

Appendix C: Streetlight

Streetlight Data is a web-based data collection and analysis service. It was founded in 2011 to provide the transportation industry with more viable data. Streetlight gathers this data by using mobile phones as sensors via local based services. These services use the cell phone GPS provided by willing users. Streetlight then provides members of the transportation industry with this data on demand.

Streetlight Algorithm

The collected data is analyzed using "machine learning and deep transportation knowledge" (Streetlight Data, About, 2011 - 2021). Machine learning allows computers to use statistics to analyze large sums of data to find patterns (*What Is Machine Learning?*, n.d.). Machine learning has a number of layers where the computer applies operations to the data. More layers equals finer pattern recognition at the cost of processing time. Deep transportation knowledge, and deep machine learning in general refers to the number of layers that the machine learning algorithm uses. The number of layers required to make an algorithm "deep" is fairly undefined, but generally assumed to be at least three (Deng, 2014). Streetlight uses the multiple layers of this algorithm to analyze the fine details in the traffic data.

Potential Application

One of Streetlight's main uses is viewing the traffic in any area or on any road. This allows it to provide a good understanding of the traffic flow around certain areas. This can be done in Streetlight by setting up a zone or gate. A zone is a polygon that encompasses the area of interest. Gates are segments that are placed on specific locations of roads that collect data when users cross the gate. Once the zones and gates are set up, the data can be analyzed in five different ways: Modular Analysis, Exploratory Analysis, Average Annual Daily Traffic (AADT), Segment Analysis, and Turning Movement Counts. Modular Analysis determines travel patterns using geospatial filters. Exploratory Analysis determines what routes and geographies interact with the geospatial filters. AADT measures the average traffic anywhere. Segment Analysis obtains trip information for specific road segments from one pass-through-gate to another. It also allows users to locate specific traffic problems and locations. Turning Movement Counts figures out the directional movement at an intersection. This means Streetlight can be used to conduct a before and after study when a new traffic system is put in place.

Appendix D: Brew Survey

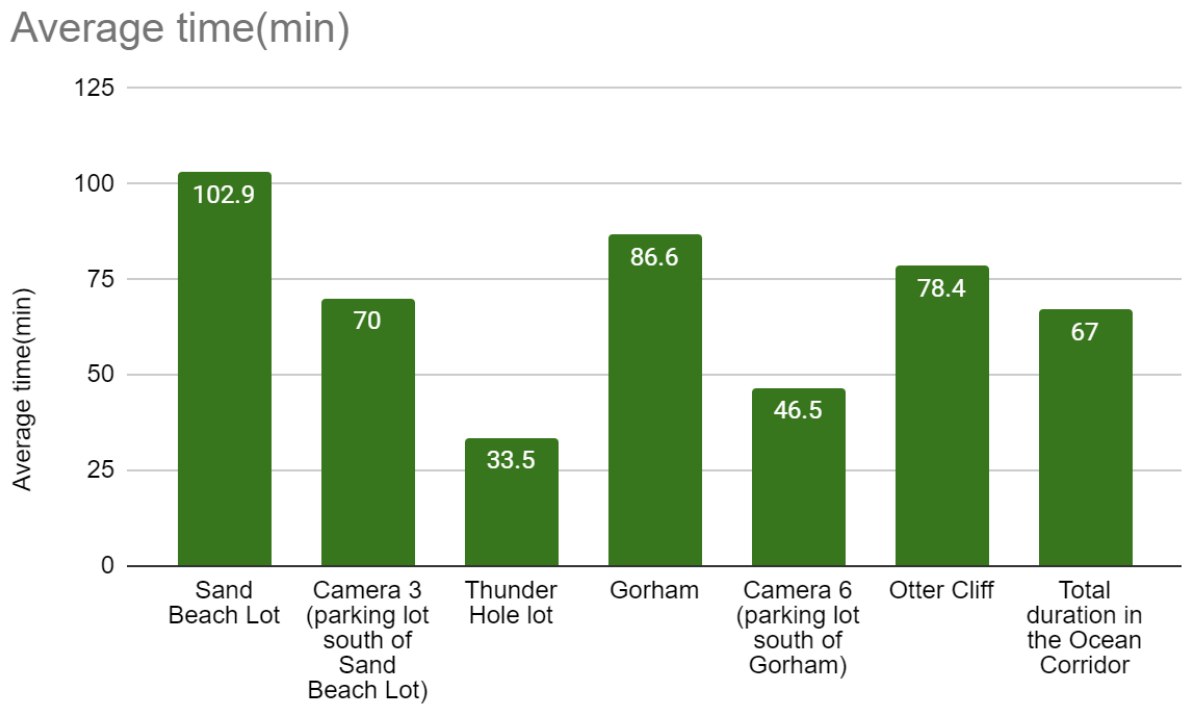
Brew Survey is "a data collection and mobile survey app" that can be used offline via smartphone (*Offline & Online Survey App for Android, IPad, Mobile Survey App*, n.d.). The app downloads surveys from the user's account and allows the user to record an unlimited number of responses. These responses are stored offline in the app until a stable wifi connection is available. Once wifi is established, the recorded responses can be uploaded and synced with Brew Survey's servers, allowing the data to be accessed. The Ocean Drive Corridor's unusable cell reception makes Brew Survey's offline capabilities an important feature. This feature allowed us to administer questionnaires to visitors on the ground easily and intuitively with our tablets.

Appendix E: Traffic Monitoring

Before Acadia can formalize a reservation system more information is needed. This project will be built upon previous traffic monitoring along the Ocean Drive Corridor (Barakian, Golias, Kirsh, Zhang 2020). Previous researchers monitored traffic in many parking lots along the Ocean Drive Corridor. They tracked vehicles through use of trail cameras to obtain qualitative information on number of vehicles and average length of stay.

Figure E.1

Bar Graph with average time per location (Barakian, Golias, Kirsh, Zhang 2020)



It is apparent that a National Park can successfully manage traffic around its attractions given the right policies. Acadia National Park appears to have done this successfully for its Cadillac Mountain visitors but still has work to be done in other areas of the park like Sand Beach.

Appendix F: Further Monitoring Data

Figure F.1

Duration of stay of cars parked along right hand side of the road from 6:00-8:59 arrival

Figure F.2

Duration of stay of cars parked along right hand side of the road from 9:00-11:59 arrival

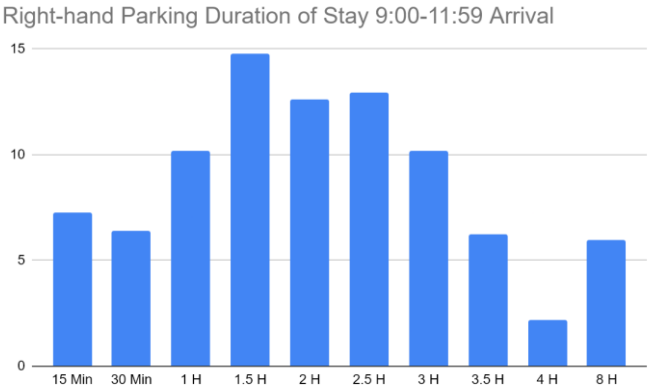


Figure F.3

Duration of stay of cars parked along right hand side of the road from 12:00-14:59 arrival

Figure F.4

Duration of stay of cars parked along right hand side of the road from 15:00-17:59 arrival

Figure F.5

Duration of stay of cars parked in the Sand Beach Parking Lot from 3:00-5:59 arrival

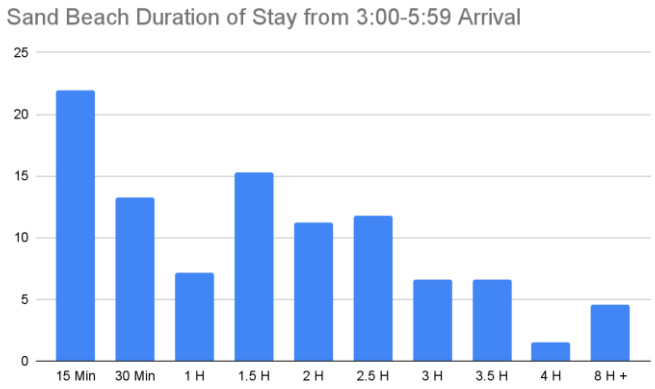


Figure F.6

Duration of stay of cars parked in the Sand Beach Parking Lot from 6:00-8:59 arrival

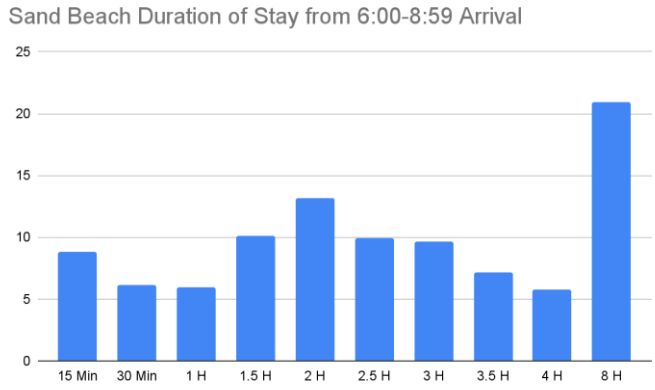


Figure F.7

Duration of stay of cars arriving in the Sand Beach Parking Lot from 9:00-11:59

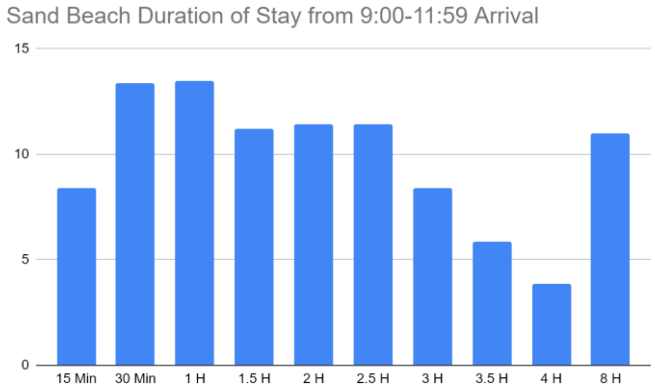


Figure F.8

Duration of stay of cars arriving in the Sand Beach Parking Lot from 12:00-14:59

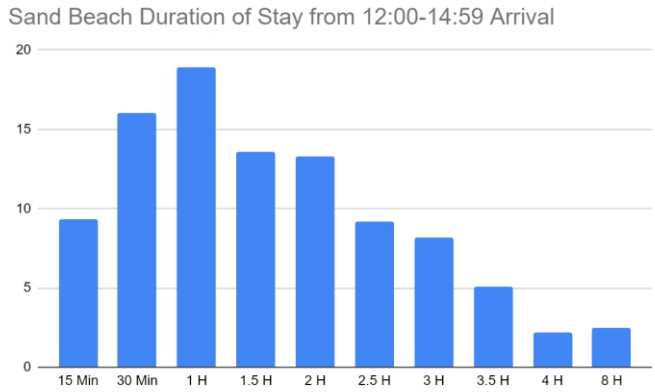


Figure F.9

Duration of stay of cars arriving in the Sand Beach Parking Lot from 15:00-17:59

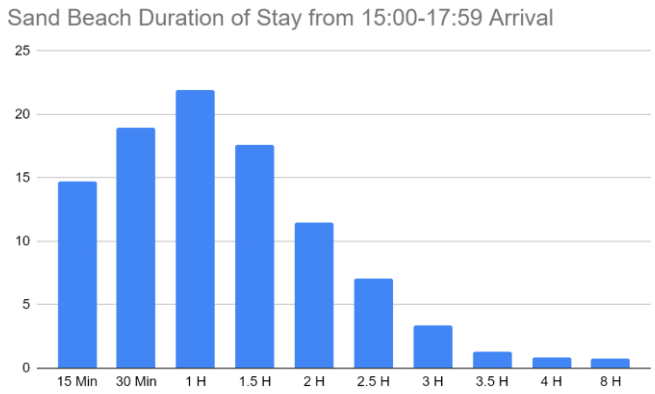
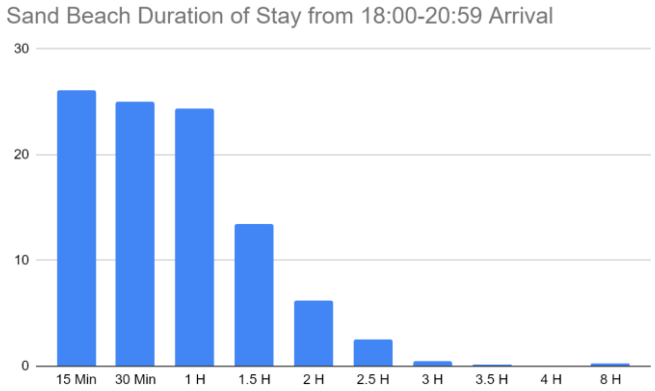


Figure F.10

Duration of stay of cars arriving in the Sand Beach Parking Lot from 18:00-20:59



Appendix G: Auxiliary Streetlight Data

Figure G.1

Traffic that Continues on the Park Loop Road (2019)

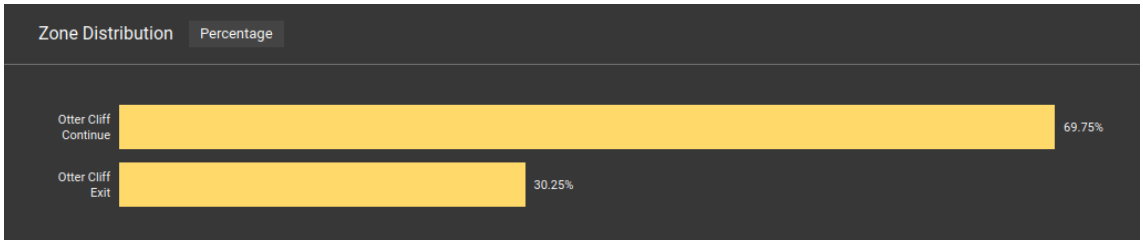


Figure G.2

Traffic destinations after leaving Sand Beach (2019)

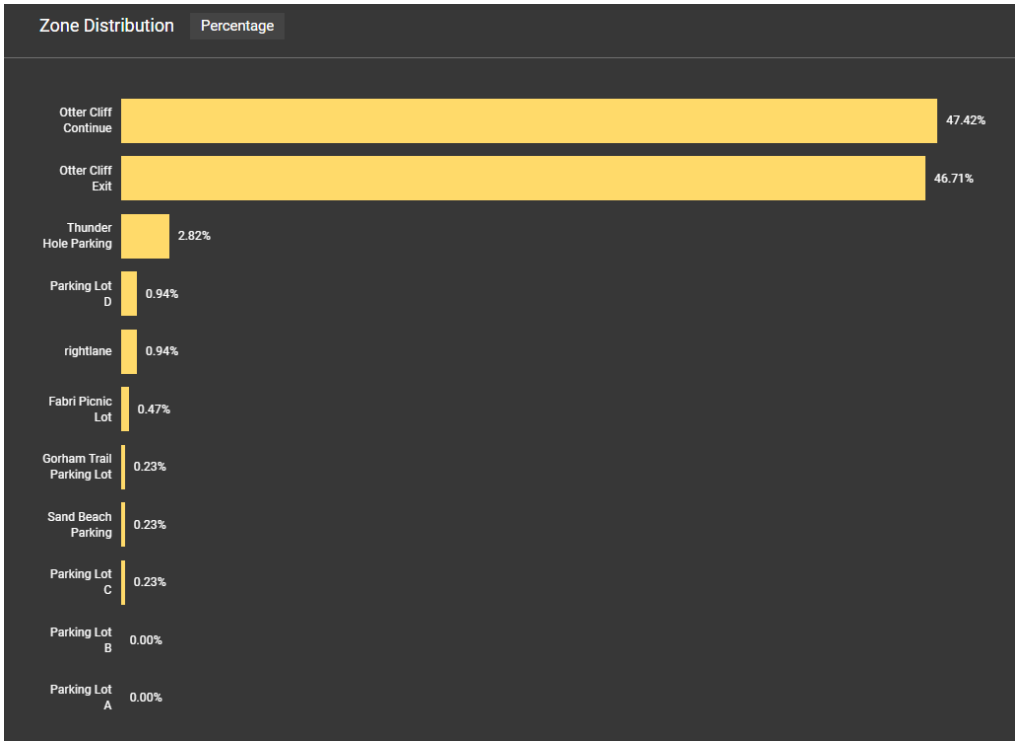


Figure G.3

Places Pedestrians go to after parking in the Sand Beach Parking Lot (2019)

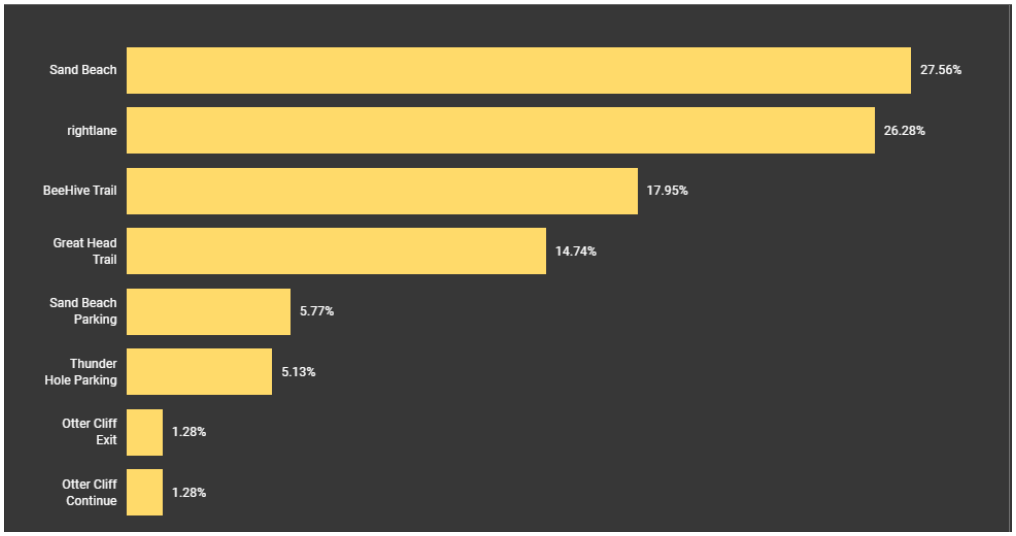


Figure G.4

Sand Beach Parking Lot Arrival Time (2019)

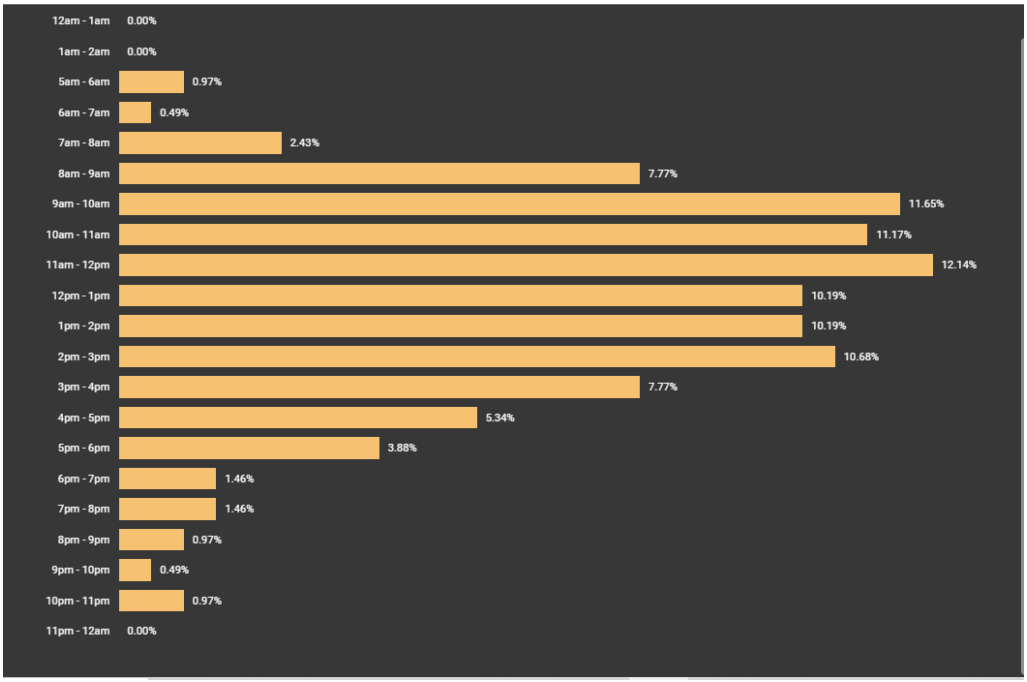


Figure G.5

Sand Beach Parking Lot Departure Times (2019)

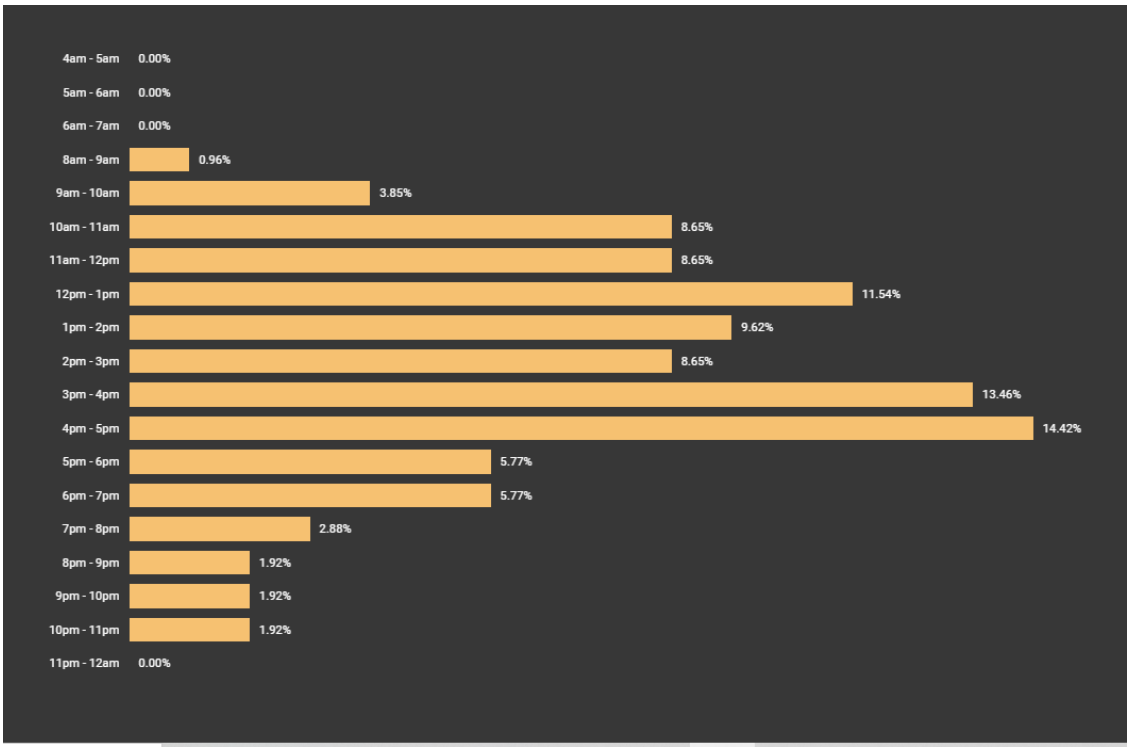


Figure G.6

Sand Beach Parking Lot Arrival Time (2020)

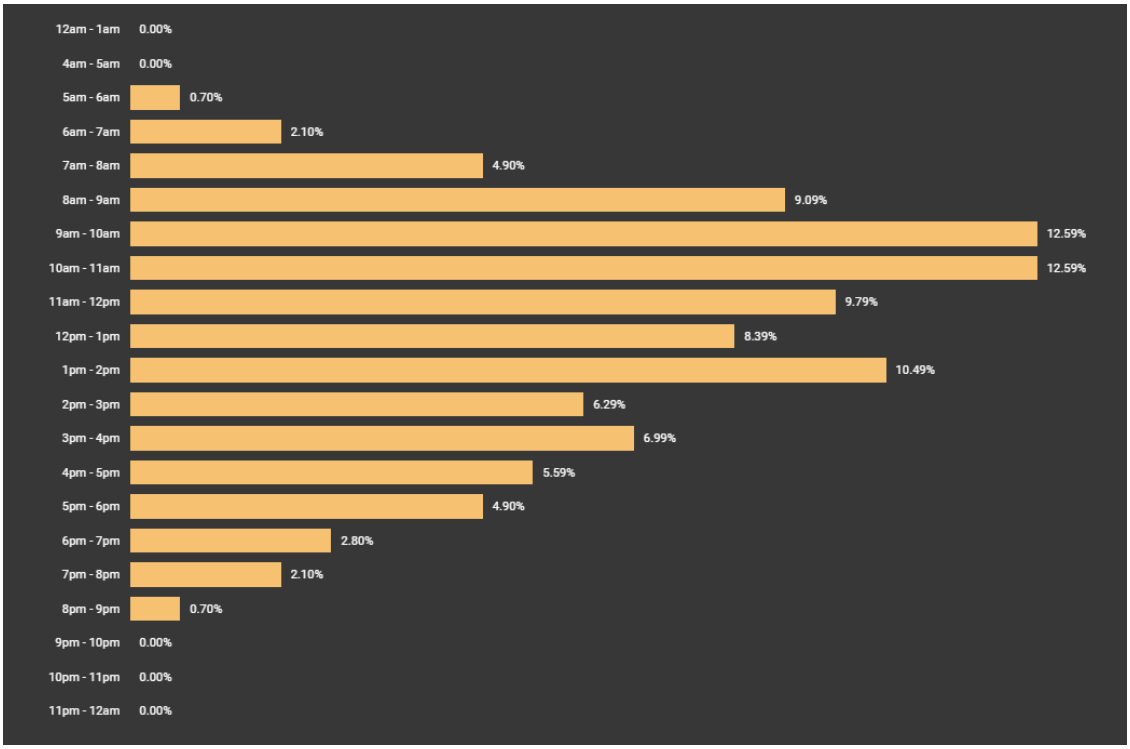


Figure G.7

Sand Beach Parking Lot Departure Times (2020)

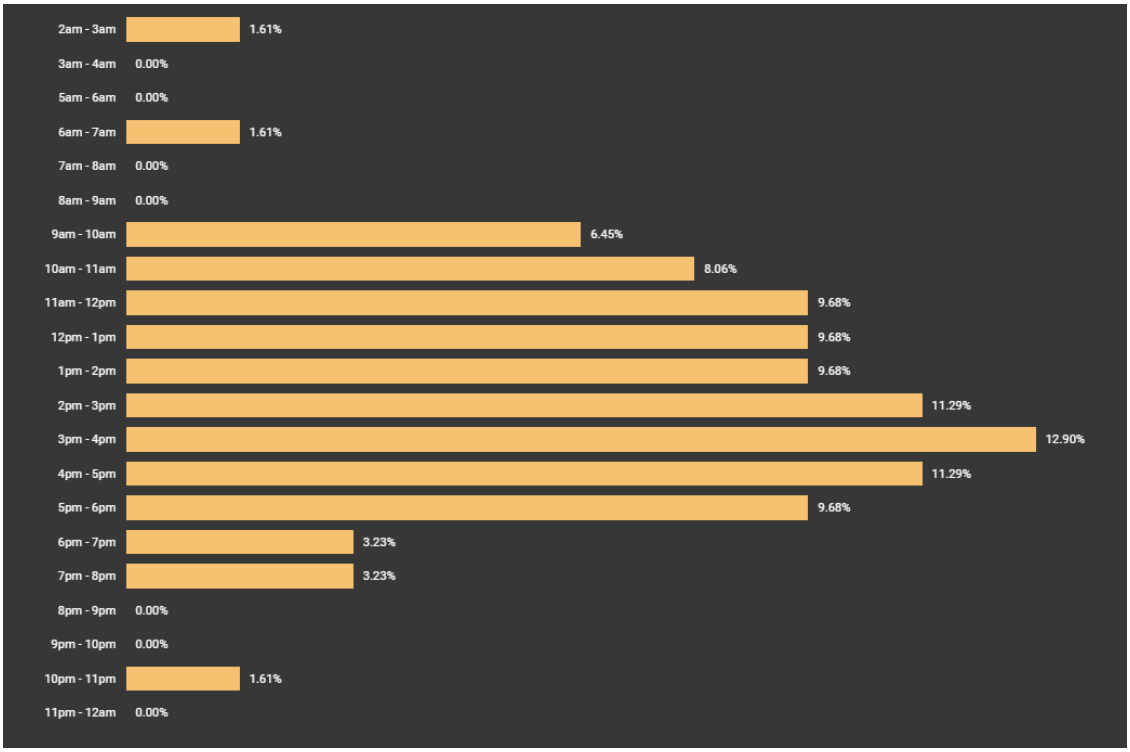


Figure G.8

Sand Beach Parking Lot Arrival Time (2018)

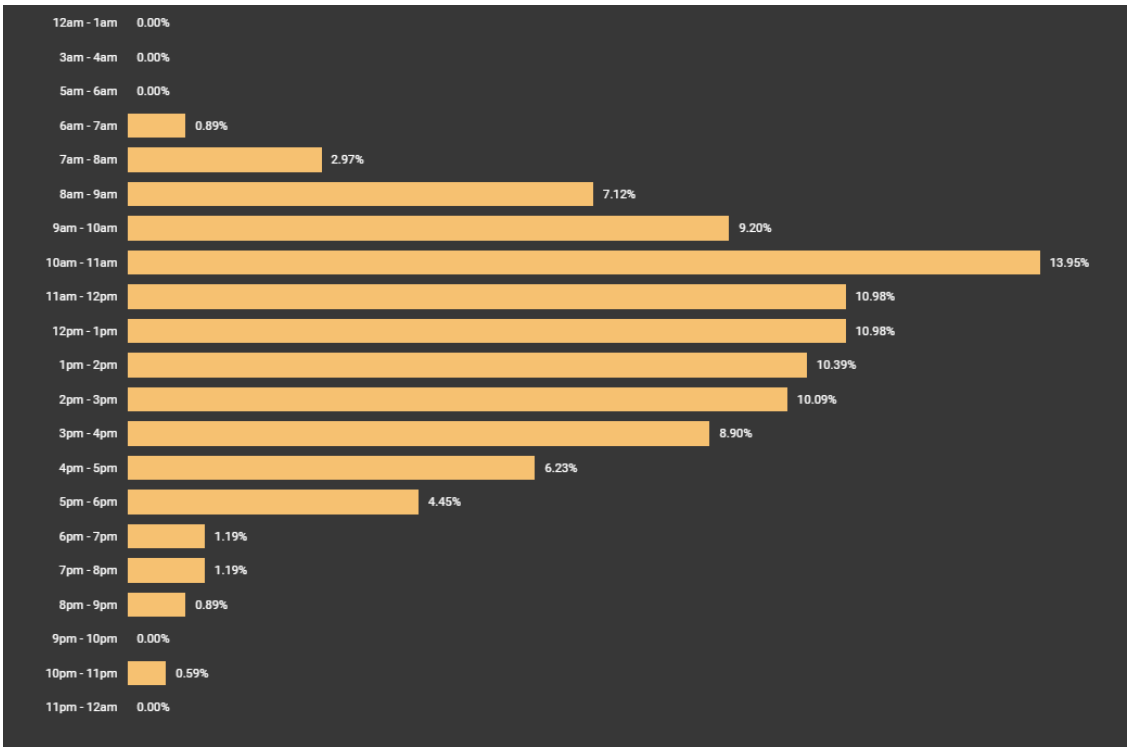


Figure G.9

Sand Beach Parking Lot Departure Times (2018)

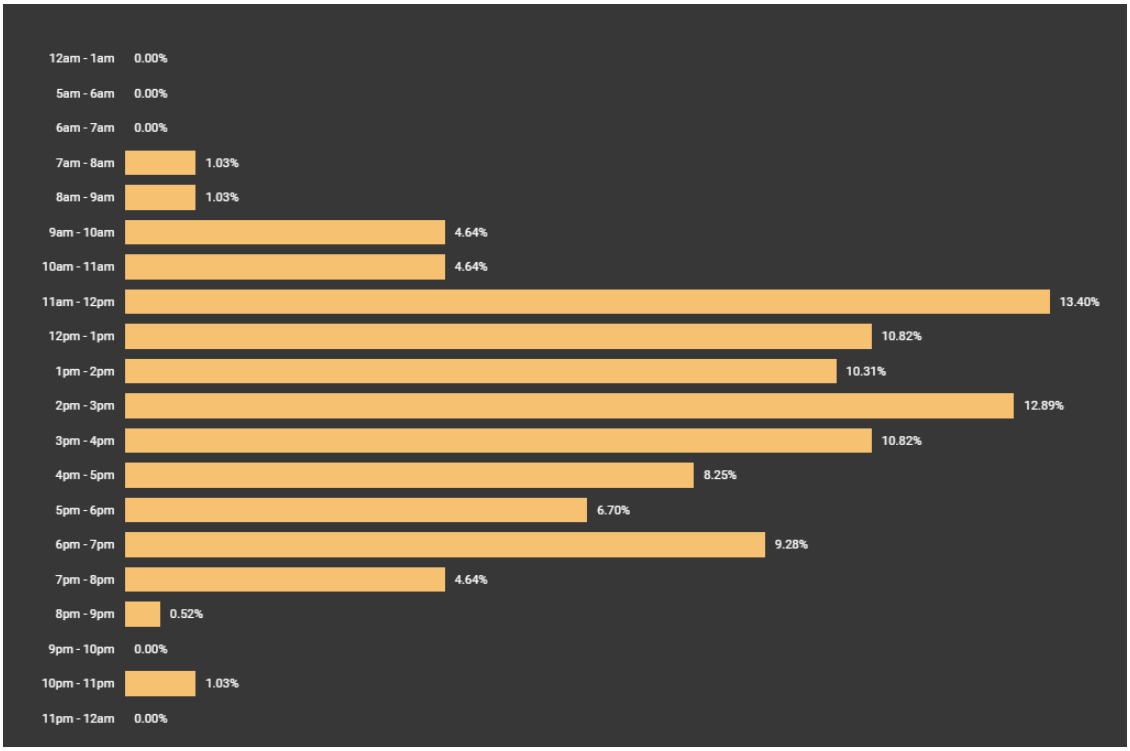


Figure G.10

Right Lane Parking Arrival Times (2019)

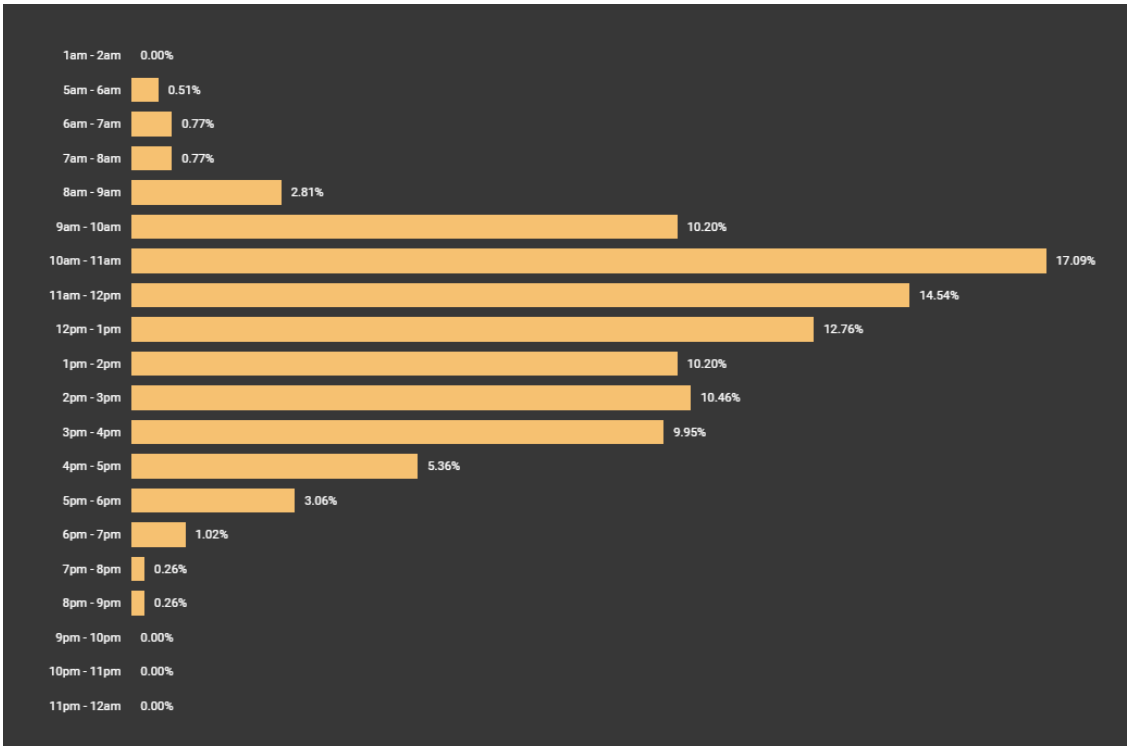


Figure G.11

Right Lane Parking Departure Times (2019)

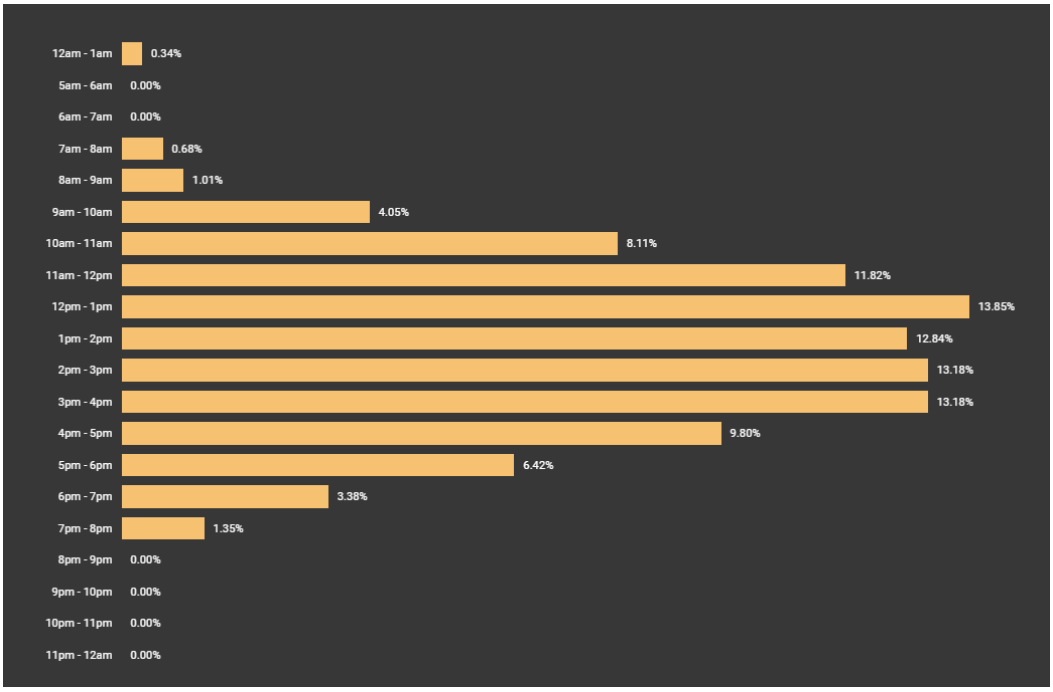


Figure G.12

Right Lane Parking Arrival Times (2020)

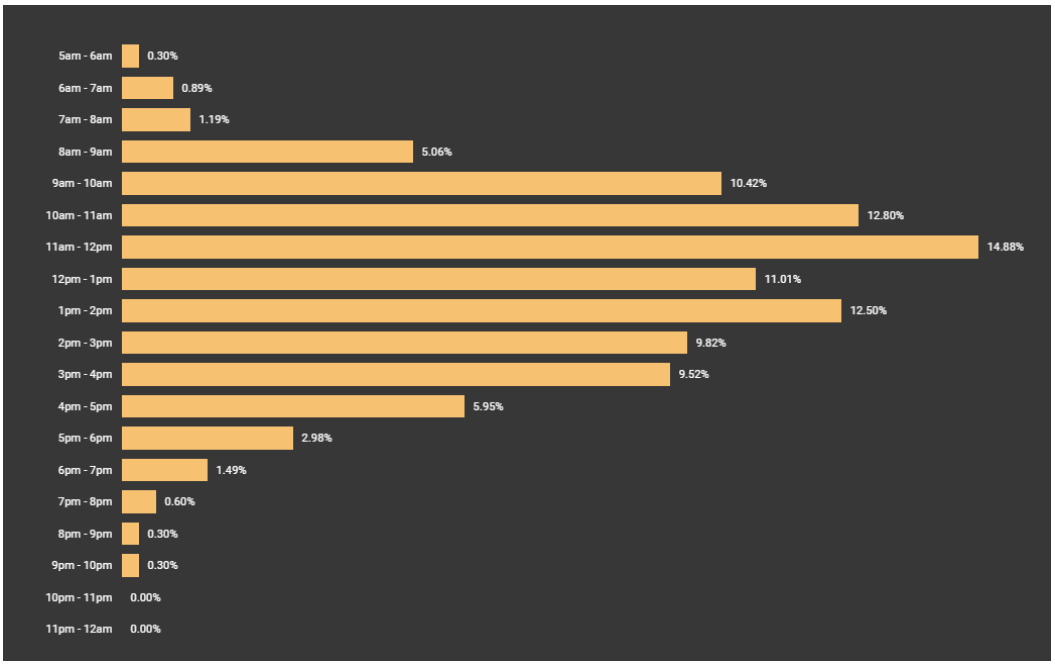


Figure G.13

Right Lane Parking Departure Times (2020)

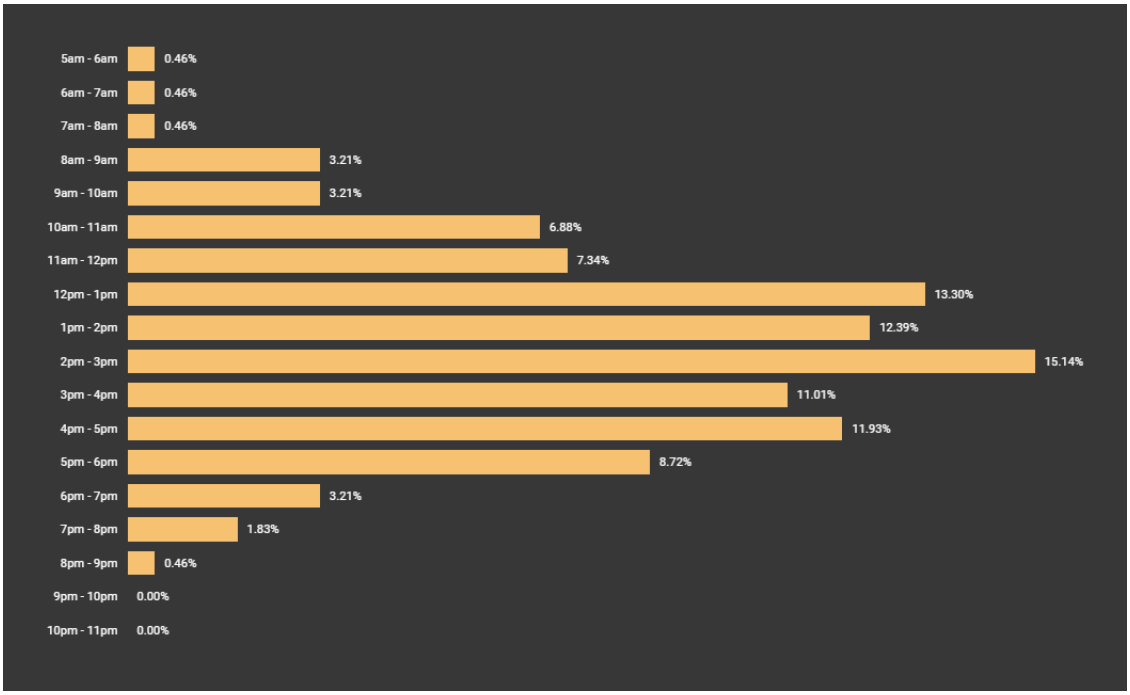


Figure G.14

Right Lane Parking Arrival Times (2018)

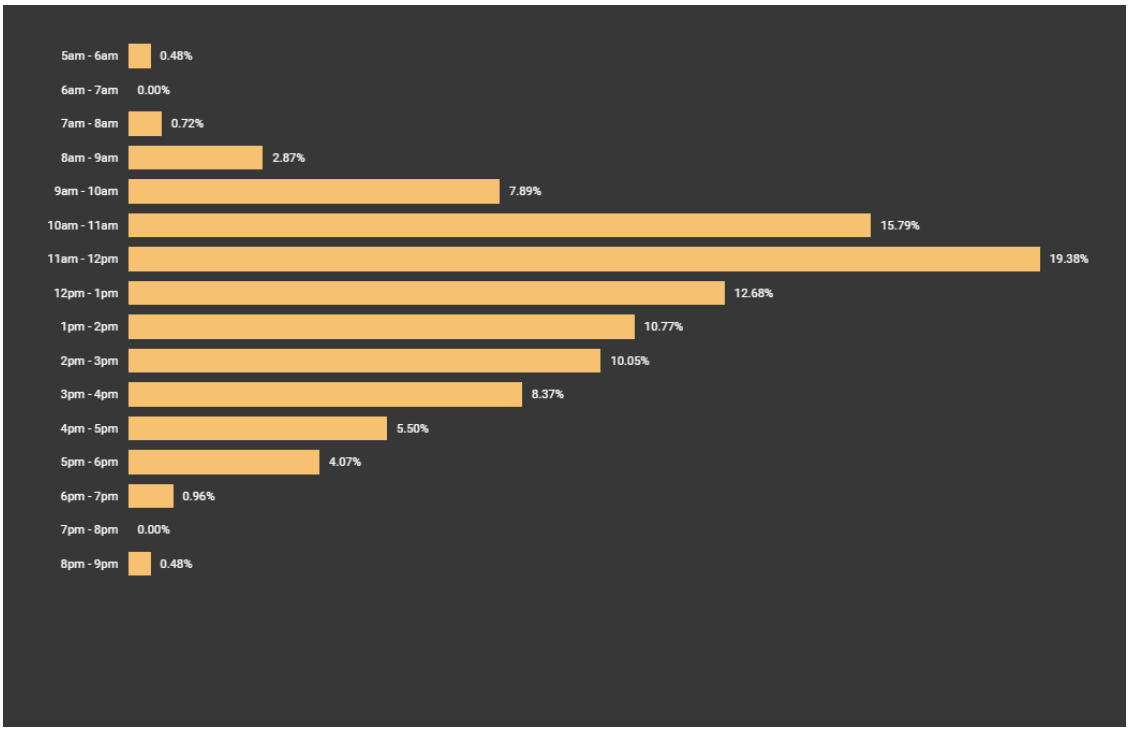


Figure G.15

Right Lane Parking Departure Times (2018)

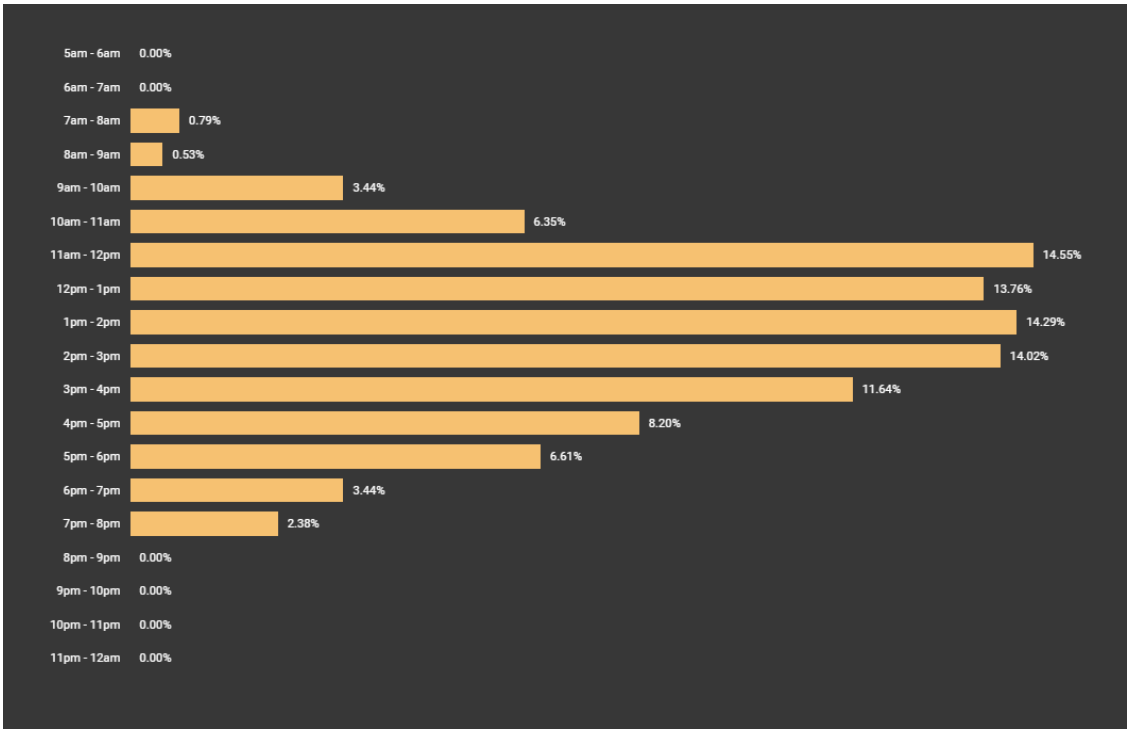


Figure G.16

Where People Go After Entering the Entrance Station (2019)

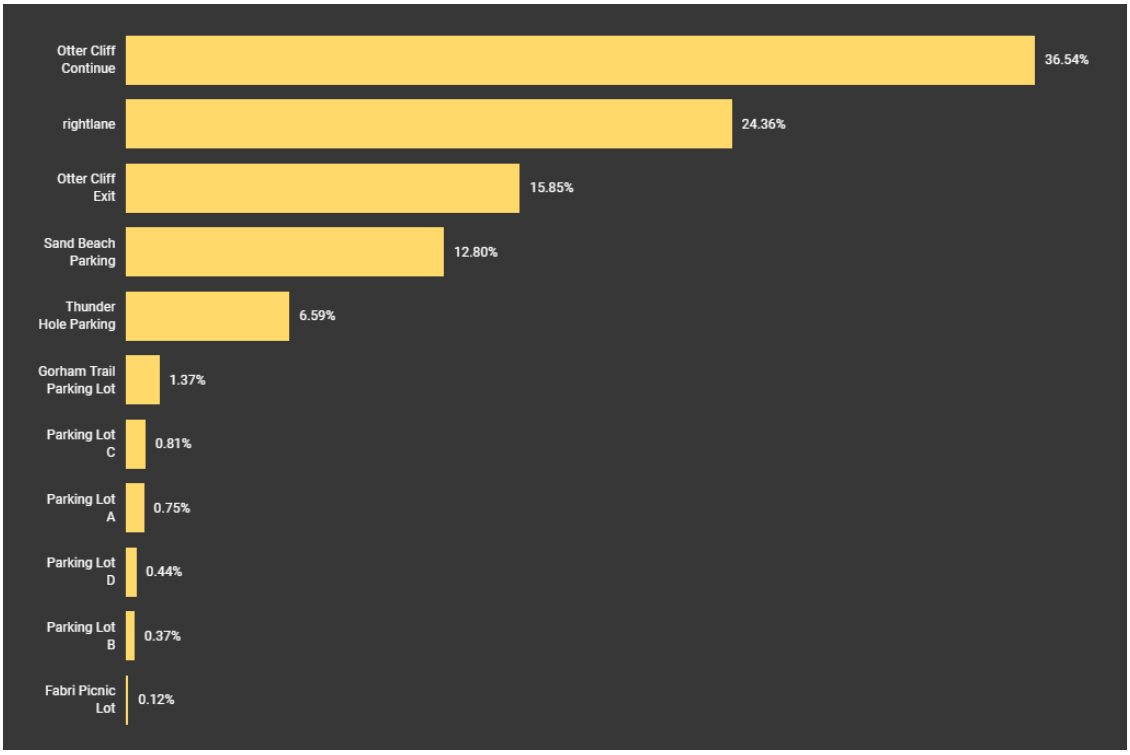


Figure G.17

Where People Go After Entering the Entrance Station (2020)

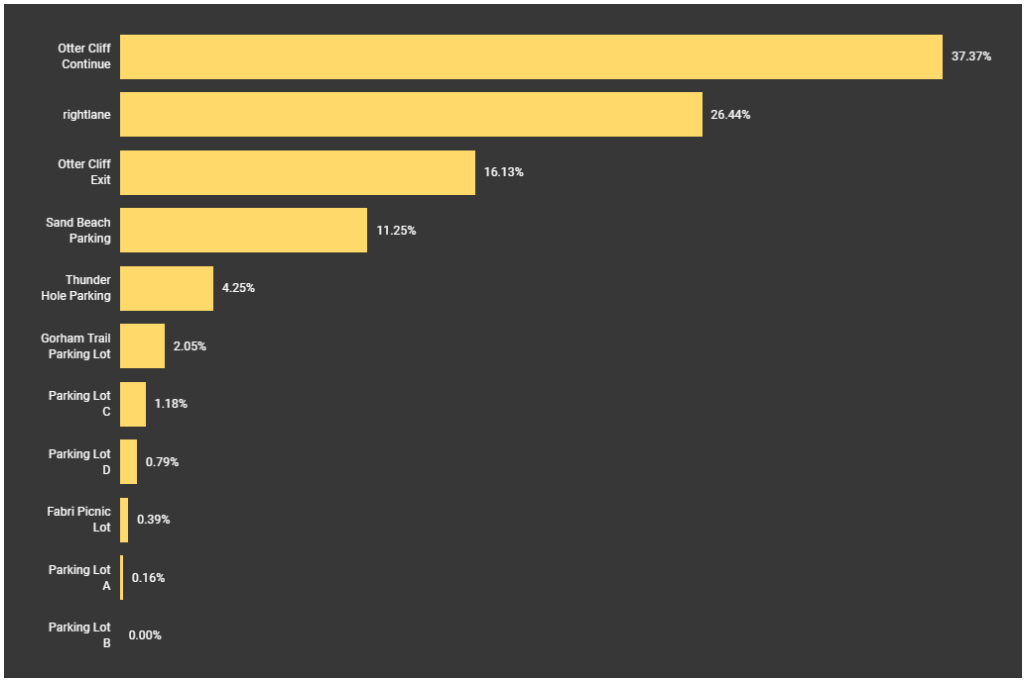


Figure G.18

Where People Go After Entering the Entrance Station (2018)