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Intelligent Transportation in Acadia National Park

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INTELLIGENT TRANSPORTATION IN ACADIA NATIONAL PARK

Determining the feasibility of smart systems to reduce traffic congestion

An Interactive Qualifying Project Report

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by

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Abstract

The goal of this project was to assess the feasibility of implementing an intelligent transportation system (ITS) in Acadia National Park. To this end, the features of an ITS were researched and discussed. The components of Acadia's previous ITS were recorded and their effects evaluated. New technologies to implement, replace, or upgrade the existing ITS were researched and the companies providing these technologies were contacted and questioned for specifications regarding their devices. From this research, three sensor systems were identified as possibilities. These sensors were magnetometers, induction loops, and cameras. Furthermore, three methods of information dissemination were identified as useful to travelers. Those methods were dynamic message signs, websites, and mobile applications. The logistics of implementing these systems were researched and documented. A cost analysis was created for each system. The TELOS model of feasibility was then used to compare the strengths of each sensor in five categories: Technical, Economic, Legal, Operational and Schedule. Based on the results of the TELOS and cost analyses, the sensors were ranked in terms of feasibility; magnetometers were found to be the most feasible, followed by induction loop sensors and then camera-based systems. The team recommended implementation of an intelligent transportation system using magnetometer sensors to monitor the Sand Beach parking lot, a dynamic message sign at the entrance station to display collected parking data, and a website to inform guests before entering the park. If the proposed system works well, it can be expanded to other popular locations in the future.

Acknowledgements

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Executive Summary

Acadia National Park, located on Mount Desert Island in Maine, is the eighth most popular national park in America. Acadia is also the 13th smallest national park, which means that the density of tourists during peak season is quite high. Since 90% of visitors bring private vehicles, the park has to deal with significant traffic congestion (Zimmerman, Coleman, & Daigle, 2003).

In 2001, Acadia staff attempted to address the growing problem with the implementation of an intelligent transportation system (ITS). An intelligent transportation system is a system for collecting, analyzing, and disseminating traffic information in real time. The system aims to mitigate traffic by informing travelers about congested areas. An example of how an ITS can work is shown in Figure 1 below.

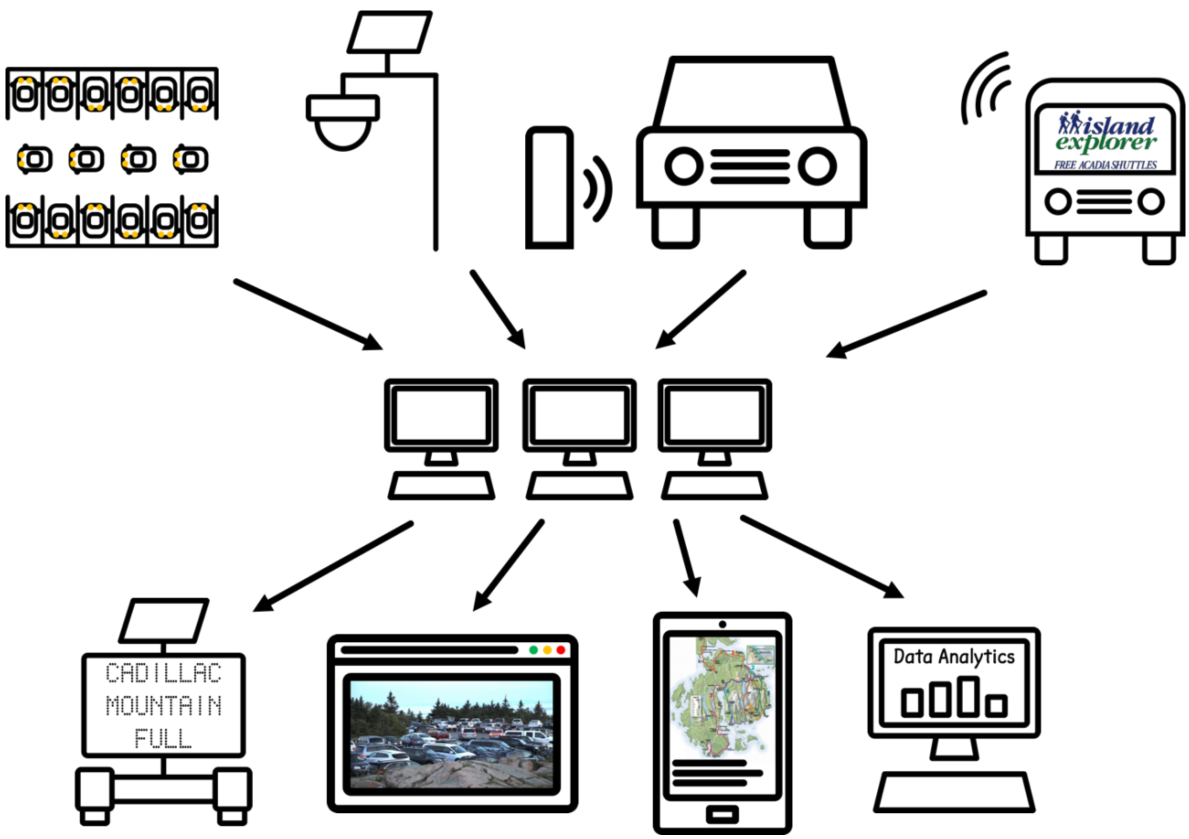

Figure 1: Example components for information collection and dissemination in an ITS

The system in Acadia had many components which can be found in Table 1. The original ITS included additional components for the public transportation system called the Island

Explorer shuttle. The system also included sensors at park entrances to determine visitor counts, cameras to monitor the Sand Beach and Blackwoods Campground parking lots, static signs to display if parking lots were full, and a visitor information phone line.

Island Explorer Two-way Voice Communications	Automatic Vehicle Locator for Island Explorer	Departure Sign for Island Explorer
Automated Annunciator for Island Explorer	Passenger Counter for Island Explorer	Parking Lot Monitoring
Automatic Ranger/Vehicle Geo-Location	Entrance Traffic Volume Recorder	Traveler Information Systems

Table 1: Components from the ITS implemented in Acadia National Park in 2002

The objectives of this team were to evaluate the functionality of the 2002 intelligent transportation system, investigate the capabilities of current intelligent transportation technologies, and assess the logistics of implementing these technologies.

For this project the team focused on monitoring parking lots and providing that information to visitors. This would allow visitors to make more informed decisions about what attractions to visit and when to visit them.

To facilitate monitoring, several methods of car counting were investigated. Each method needed to be able to accurately provide the current number of spaces available. Three methods in particular were investigated: magnetometer sensors, induction loop sensors, and cameras.

Magnetometers work by detecting the change in magnetic field caused by passing vehicles. Sensors are typically mounted on a post at engine level or below the road surface. The sensors do not detect direction so one sensor is needed for each entry or exit to a parking lot.

Induction loop sensors function in a similar manner to magnetometers. However, induction loops are always buried in the pavement and then sealed. Cars passing over the sensor induce an electric current; this change in current alerts the sensor that a car has passed overhead.

Camera based systems function differently. Camera-based systems rely on image recognition software to determine if a parking space is empty or full. For a camera-based system to work, the camera has to have line of sight to every parking space. For some irregularly shaped parking lots, this makes camera-based systems highly undesirable as many cameras would be required to see every space available.

Once the information has been collected, dissemination of the information to park visitors is necessary. Three methods were examined for communicating information including dynamic message signs, websites, and mobile applications.

Dynamic message signs displaying the number of spaces available in a given parking lot should be placed a few hundred yards before the parking area to give visitors adequate time to make parking decisions. These signs can also help reduce roadside parking by providing advanced warning of space availability.

A website displaying parking information and predicted congestion levels can allow visitors to make informed decisions before getting on the road and allow people to plan out where and when they want to go to avoid traffic.

A mobile application would provide the same benefits as a website but can provide visitors with static information when visitors lack data service.

Data gathered from the system can be stored in the long term to provide useful trends to the park and visitors. Predictive models can be compiled using the collected data, date, time, weather conditions, and more.

The recommendation of this team is to implement an intelligent transportation system to monitor the parking conditions at Sand Beach using magnetometer sensors and expand the system after observing its success. The system should include a dynamic message sign near the Park Loop Road entrance station displaying the number of parking spaces remaining. This information should also be displayed on a new website and mobile application.

Authorship

Angela Calvi—Edited the entire paper thoroughly for grammar, syntax, and continuity. Authored Background: Smart solutions to tourist related traffic congestion; Background: Intelligent transportation systems in Acadia National Park; Recommendations.

Colin Maki—Edited for continuity and flow. Authored Background: Traffic management in national parks; Contributed to Results and Analysis: Objective 3.

Jackson Peters—Edited for content. Authored Abstract; Executive Summary; Introduction; Background: Tourism and subsequent traffic congestion in Acadia National Park.

Mingqi Shuai—Edited for content. Authored Background: Traffic management in national parks; Background: Intelligent transportation systems in Acadia National Park; Results and Analysis: Objective 1; Results and Analysis: Objective 2; Results and Analysis: Objective 3.

Daniel Wivagg—Edited for structure and content. Authored Background: Tourism and subsequent traffic congestion in Acadia National Park; Methods; Results and Analysis: Objective 1; Results and Analysis: Objective 3; Results and Analysis: Implementation logistics at Sand Beach; Conclusion.

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Introduction

In the United States, national parks are meant to be the answer to environmental degradation: a series of land parcels set aside and preserved in their natural state, protecting these areas for future generations. While the purpose of the parks is for preservation, a significant amount of infrastructure including roads, bridges, and parking lots was built in and around each park for visitor access soon after the inception of the parks. In Acadia National Park, located primarily on Mount Desert Island, Maine, the number of annual visitors, and thus the number of cars has been steadily increasing; this has overwhelmed the infrastructure that was created to accommodate visitors in the 1930s and 1940s. Overhauling the infrastructure by expanding roads and parking lots would destroy protected land and cannot solve the problem of growing congestion indefinitely. A flexible, park-friendly solution is necessary: one that maximizes tourist capacity and minimizes environmental impact.

Some parks in the U.S. have made attempts to solve their traffic problems, with places like Zion National Park in Utah having entirely banned cars for private use within the park's boundaries and requiring visitors to use the park shuttle (Mace, Marquit, and Bates, 2013). Other parks are also using shuttles to reduce traffic: Rocky Mountain National Park and Grand Canyon National Park have been utilizing signs to inform visitors of their shuttle system and encourage ridership (Villwock-Witte, Eidswick and Miskimins, 2014; Ye et al, 2010). The traffic management technology used in some parks is modeled after systems used in other notoriously crowded areas. The city of Seattle, Washington encourages a mixture of traffic management and public transit using an intelligent transportation system (ITS), which is the broad name for a traffic management system that processes transportation data in real time. ITS allows the Seattle Department of Transportation to make real-time updates on traffic conditions by using changeable advisory signs to alert travelers of car crashes and suggest alternative routes.

Like Zion, Rocky Mountain, and Grand Canyon, Acadia National Park has implemented its own shuttle system called the Island Explorer which runs a series of nine routes around Mount Desert Island and the Schoodic Peninsula (Downeast Transportation, 2017). In a study of the Island Explorer, Robert Manning, a renowned author of countless studies on Acadia National Park, and his associates discovered that tourists were more likely to take the shuttle when parking conditions were displayed online (Manning, 2009). Since then, the shuttle system has incorporated online tracking and electronic signs at many of its stops to inform visitors of bus locations and arrival times, making use of the Island Explorer both practical and efficient. In his research, Manning also surveyed business owners in Bar Harbor about their thoughts on a new system to ease traffic. Of those interviewed, 85% supported a monitoring system that tracked available parking and updated this information through a website. While Acadia has implemented a highly utilized shuttle system, other ITS technology like a monitoring system that tracks available parking spaces have yet to be incorporated into the park.

This project was intended to assist Acadia National Park in addressing the issue of traffic congestion by providing an analysis of the overall feasibility and implementation logistics of additional ITS components. The team evaluated the remaining components of Acadia's original ITS, investigated the capabilities of commercially available ITS technologies, and assessed the feasibility of several potential systems.

Background

Tourism and Subsequent Traffic Congestion in Acadia National Park

The visitor experience in Acadia National Park is diminished by overcrowding and traffic. Robert Manning, author of countless research studies in Acadia, reported that “more than one-quarter of the summer visitors…generally find the park too crowded” (U.S. Department of the Interior, 1991, p. 23). According to the statistics of the National Park Service’s Integrated Resource Management Applications Portal on visitor use, annual visitation levels have exceeded two million people every year since 1966, and have risen steadily in the past 3 years to surpass three million in 2016 (National Park Service, 2017). Of these three million visitors, over 90% bring their personal vehicles to the park annually (Zimmerman, Coleman, & Daigle, 2003). Vehicular traffic is concentrated on Park Loop Road, especially the segment of road known as Ocean Drive, and obstructs natural scenery and landscape, further reducing visitor satisfaction (Steinitz, 1990, Hallo and Manning, 2010). Due to the increase in tourist counts and associated vehicular traffic, visitors are unable to enjoy the solitude, landscape, and scenery of the park that attracted them in the first place.

Vehicular traffic drastically affects perceived congestion in the park. In 2003, Robert Manning and his colleagues attempted to quantify how many people visitors expected to see in different areas around the Schoodic Peninsula. Their results indicated that visitor satisfaction began to suffer once the number of people was twice what a visitor expected. Furthermore, when vehicles are parked on the roadside, the perceived congestion within the park doubles (Bacon et. al, 2003). Thus, car traffic can very easily diminish the visitor experience by making it seem like the park is more crowded than it is. During the peak season when traffic and roadside parking seem to be ubiquitous, these effects have their worst impact on visitors.

The most frequented areas of the park are the most prone to damage and destruction. Park Loop Road, which circuits the park, was designed as a scenic road to showcase some of the most beautiful views the park has to offer (U.S. Department of the Interior, 1991). As a result, there is an excess of roadside parking and congestion as drivers pull over to admire the scenery. Additionally, popular attractions with parking lots nearby are prone to overcrowding in the lots. In 2016, a research team at Acadia National Park determined how full each parking lot around Park Loop Road was during three time periods throughout the day. Their research, shown in

Table 2, indicated that certain attractions (highlighted) remained full for most of the day while others had little visitation. The following areas were most popular: Sand Beach, Jordan Pond House, Cadillac Mountain, and Gorham Mountain (Dziuban et al. 2016). These areas, shown in Figure 2, are the most well-known attractions on Park Loop Road. Fifteen of the twenty-one locations shown in Figure 2 were observed and reported in Table 2.

Location	Average Percentage Full (%)		
	10:00-11:00	12:30-1:30	7:00-8:00
Schooner Head Overlook	12.7	26.0	3.0
Sand Beach Lot	94.3	97.0	20.5
Sand Beach Upper	87.9	**100.0**	6.8
Ocean Path 1	52.7	81.1	1.4
Ocean Path 2	25.0	71.4	0.0
Thunder Hole	45.0	59.4	18.3
Gorham Mountain Trail	98.7	92.0	6.0
Ocean Path 3	62.5	77.5	2.5
Fabbri Picnic Area	25.0	69.2	7.7
Fabbri Memorial	20.0	15.0	5.0
Otter Cliff	95.0	61.7	32.5
Jordan Pond House Main	98.6	**106.5**	49.3
Jordan Pond House Auxiliary	98.1	**107.1**	10.8
Blue Hill Overlook	46.1	21.2	130.3
Cadillac Mountain Summit	74.5	69.6	94.6

Table 2: Parking Lot Percentage Full vs. Time of Day (Dziuban et al. 2016)

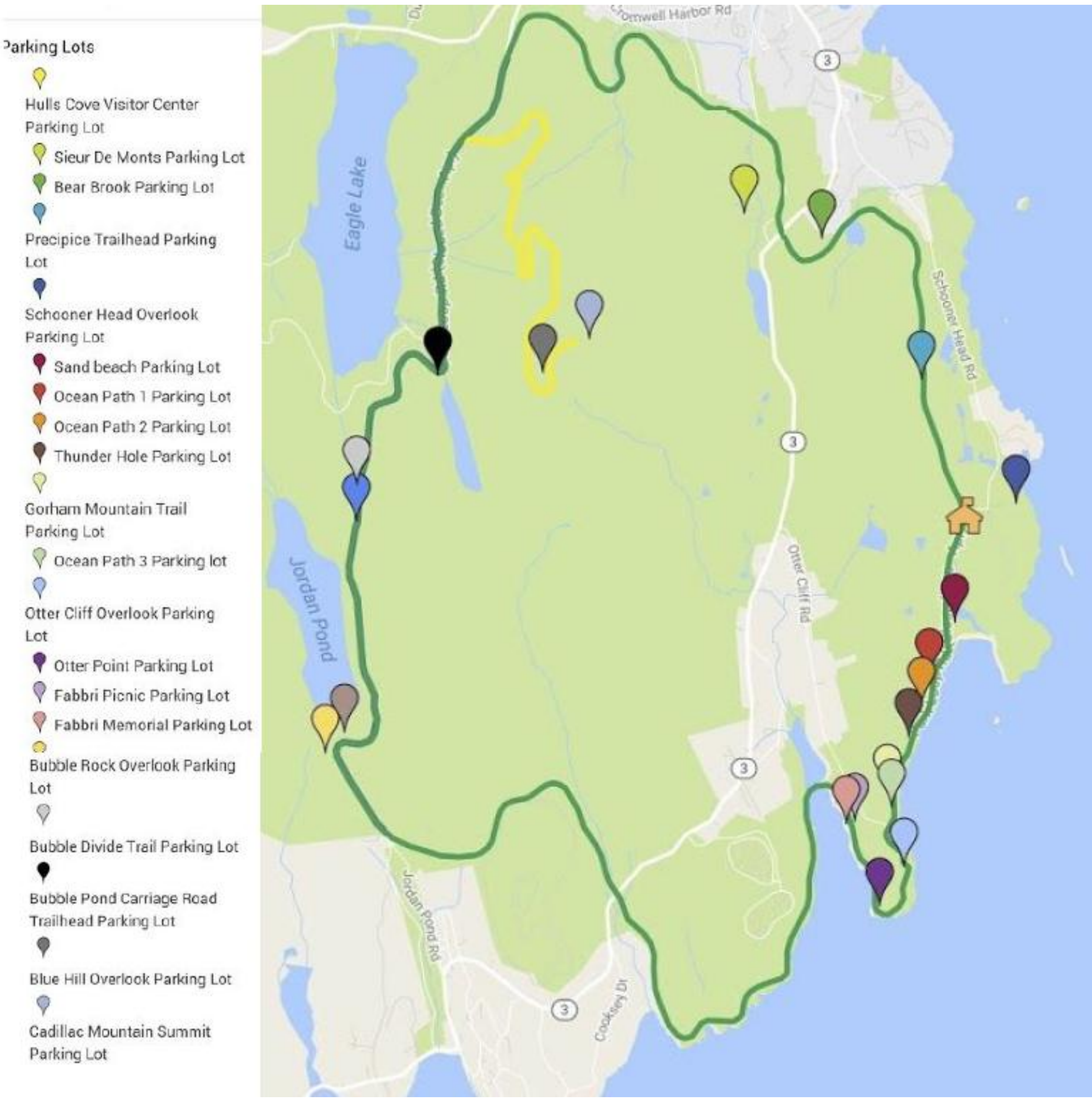

Figure 2: Map of parking lots along Park Loop Road, including Cadillac Mountain (Dziuban et al. 2016)

Acadia's small size compared to other parks of similar popularity makes congestion issues even more challenging. According to National Park Service statistics, Acadia is the 8th most visited park, but 13th smallest out of 59 national parks in America (National Park Service, 2017). Of the top ten most popular national parks, Acadia is the smallest (National Park Service, 2017). The park is only 42,000 acres large, but welcomed 3.3 million visitors in 2016. The next largest park is Zion National Park, which is three times as large and accommodated 4.2 million visitors, only a million more than Acadia, in 2016 (National Park Service, 2017). Rocky Mountain National Park is over five times as large as Acadia and had only about 4.5 million visitors in 2016 (National Park Service, 2017). The tourist congestion experienced by Acadia magnifies the impact of visitors on the environment and park officials need to make a concerted effort to reduce this impact.

Traffic management in national parks

In most cases, the solution to visitor and traffic congestion is simple: expand infrastructure around the attraction and add more space for visitors. This could include widening roads, building additional entry and exit points, or adding additional parking (National Park Service, 2014). Expanding infrastructure, however, is not a viable option for Acadia. In order to build more parking lots or expand roads, national forest would have to be cut down, construction equipment and materials brought in, and a large section of land excavated. In addition, this approach only provides a solution if numbers of tourists does not continue to increase in coming years. Since these traditional approaches to tourist congestion management are not appropriate for a natural setting, the National Park Service provided a guidebook for transportation planning to park managers in 1999. This guidebook suggested roadway modifications, traffic restrictions, promotion of off-peak park use, reservation systems, and intelligent transportation systems as possible solutions (National Park Service, 1999). Moving forward, Acadia National Park must consider appropriate solutions that align with the National Park Service guidelines and do not worsen the impact of traffic congestion.

Traffic solutions in Acadia National Park

Previously implemented solutions for traffic congestion in Acadia National Park have found some success, but none have completely addressed the growing traffic problem. The most prominent example of these implemented solutions is the Island Explorer, a free shuttle service that traverses Mount Desert Island implemented in 1999 (Hallo and Manning, 2009). The shuttle operates from June 23rd to Columbus Day, with reduced service after September 1st (Downeast Transportation Inc., 2017). One of the benefits of this service is that it removes some private vehicles from park roads. Unfortunately, the Island Explorer system is underutilized on some routes and is not large enough to accommodate the number of tourists who want to ride on others. In 2016, only 17.4% of the 3.3 million visitors rode the Island Explorer (National Park Service, 2017). The shuttle's frequency depends on the destination, with most wait times at locations around the park ranging between 30 and 60 minutes (Downeast Transportation Inc., 2017). The Island Explorer route map is shown in Figure 3.

Another approach to managing traffic congestion within Acadia is the use of manual signs to indicate whether or not a parking lot is full. In past years, the signs were posted at the Visitor Center and the entrances to two campgrounds (Zimmerman, Coleman, & Daigle, 2003). However, due to the number of responsibilities of park staff during peak visitor hours, the signs were not usually updated in a timely fashion and were sometimes entirely absent (Zimmerman, Coleman, & Daigle, 2003). Of visitors who saw the parking lot signs in front of Sand Beach and Blackwoods Campground, 74% said the information made it easier to get around (Zimmerman, Coleman, & Daigle, 2003). A sign-based system may prove to be very effective at managing private vehicle parking in Acadia if the information were displayed in a variety of locations outside of parking lots and could be updated in real time to prevent overcrowding.

The most recently implemented solution to tourist-related traffic congestion is Acadia's car-free days. In 2015, Acadia National Park began to hold two car-free days per year (Kelly, 2015). The first car-free day takes place in May and lasts from midnight to noon, and the second is in September and lasts all day in celebration of National Public Lands Day (Kelly, 2015). These car-free days enable visitors to enjoy the park through a more natural lens with reduced congestion and noise pollution. While successful in addressing the issue of tourist-related traffic congestion, the infrequency of these events limits their contribution to solving the problem.

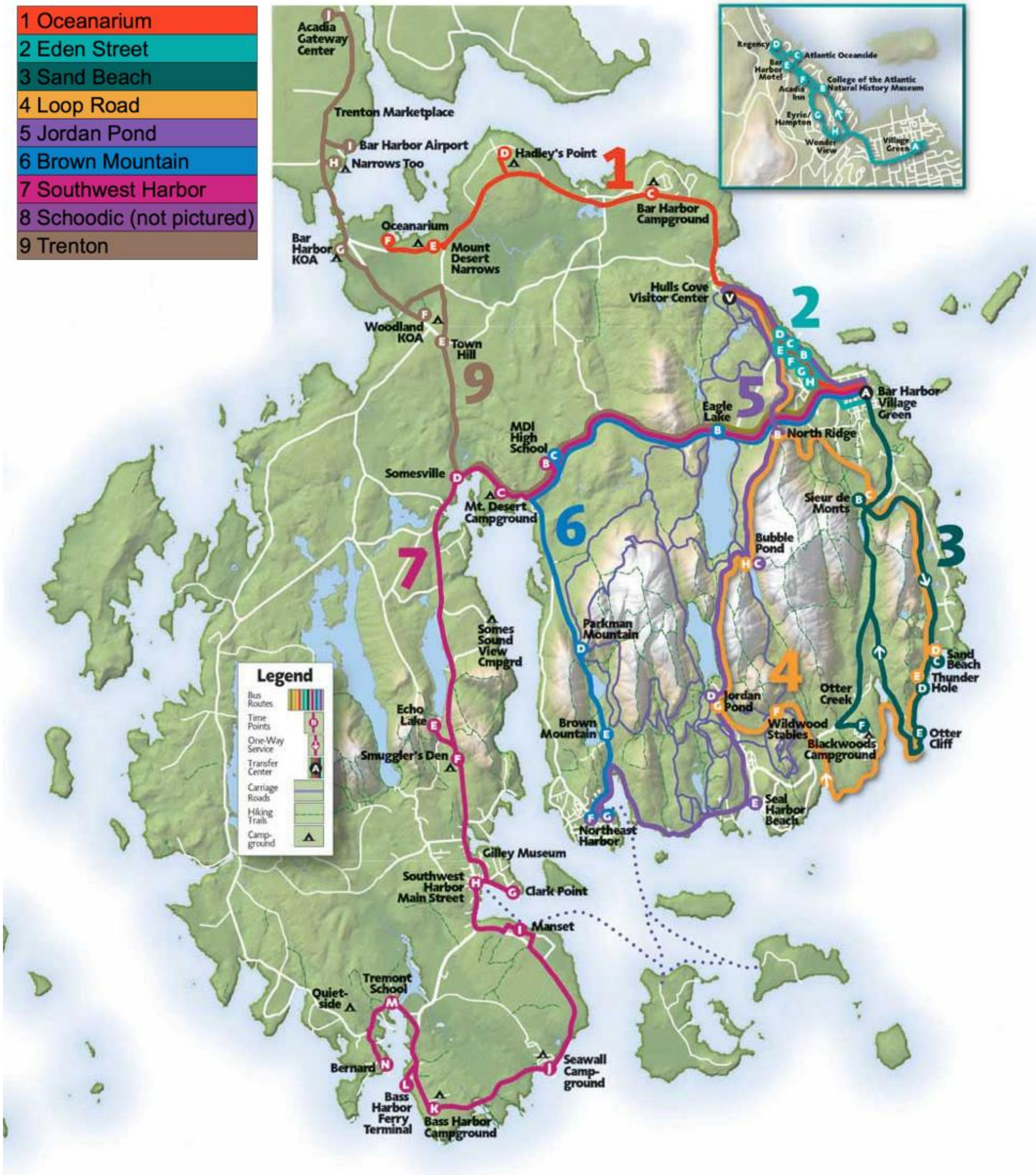

Figure 3: A map of Mount Desert Island detailing the seven Island Explorer bus routes on the main island

(System map retrieved from http://www.exploreacadia.com/fullmap.htm)

In addition to shuttles, signs, and car-free days, Acadia National Park has developed four new preliminary concepts to address traffic management on Park Loop Road (National Park

Service, 2016). The first of these involves bolstering the public transit system and reducing parking on the side of roads while introducing a new parking lot. This plan would also require visitors to make reservations during peak season for Cadillac Mountain, Jordan Pond House, and Sand Beach. The second plan involves a metering system at the entrance to the Ocean Drive segment of Park Loop Road that would allow private vehicles onto the road until a predetermined threshold is reached. This plan would also require reservations during the peak season for Cadillac Mountain and Jordan Pond House. The third plan involves repainting Park Loop Road as a one-way counterclockwise route, in the opposite direction of its current traffic flow. This plan includes new stops for public transit, new parking lots, and requires reservations for private vehicle access on Park Loop Road in the peak season. The fourth plan would make Park Loop Road two-way along its entire length. It proposes new parking and transit stops but does not allow private vehicles to use Park Loop Road during the peak season. The key locations in each plan are illustrated in Figure 4. The positive and negative aspects of the proposed components are outlined in Table 3.

Based on Table 3, the proposed components which will be most useful for mitigating traffic congestion while improving visitor experience are increased public transit and the removal of right lane parking. Components that will likely be avoided include eliminating private vehicle use, reversing the direction of Park Loop Road, and making Park Loop Road two-way. The solutions involving repainting the lanes of Park Loop Road will not reduce the number of cars traversing the park; they will only alter the distribution of traffic instead of reducing it. The solution of preventing private vehicles from entering the park is also suboptimal since many visitors still wish to view the park from their own vehicle (Hallo and Manning, 2009). The solutions involving a metering or reservation system could have positive impacts on visitor experience, but would need to be expanded as to not limit the number of visitors the park receives.

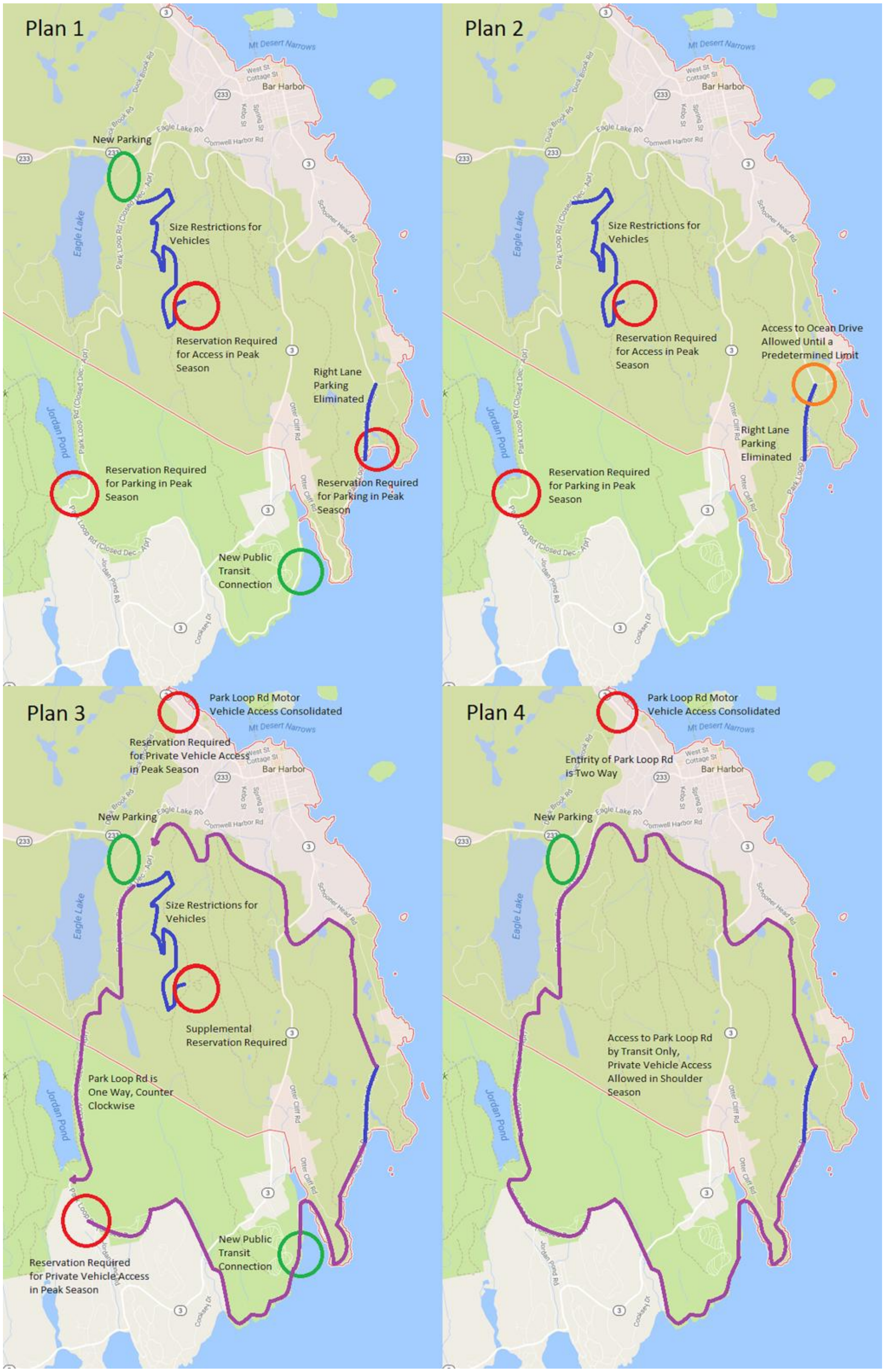

Figure 4: Mount Desert Island concepts for traffic management (Map retrieved from Google Maps)

Proposed Component	Positive	Negative
Increase Public Transit	• Increases availability of areas accessed by reducing right lane parking	• Expensive investment by the park and donors
Remove Right Lane Parking	• Vehicles can maneuver the roads more easily • Improved safety for cyclists and pedestrians	• Less parking within the park, especially on Ocean Drive
New Parking Lot	• Reduces informal parking at Eagle Lake	• Causes damage to the environment
Reservation System	• Reduces the number of vehicles and improves traffic flow	• Limits the number of visitors to those with a reservation
Metering System	• Will not allow Ocean Drive to exceed its carrying capacity	• Will cause a buildup of cars waiting to access the park
Reverse One-Way, Park Loop Road	• Improves safety for cyclists and pedestrians • Allows for better scenic views for slower moving traffic	• Will not reduce the amount of traffic
Two-Way, Park Loop Road	• Increase vehicle maneuverability throughout the park	• Traffic flow must be balanced between the two directions • Drivers want to enjoy scenery without worrying about oncoming traffic
Stop Private Vehicle Use	• Clears the roads of all congestion	• The vast majority of park visitors use private vehicles

Table 3: Positive and Negative Effects of Implemented Components

Traffic solutions implemented in other parks

Banning private vehicle access to park roads is a common method of reducing tourist congestion in national parks. In Zion National Park, a mandatory shuttle was implemented in 2000 to manage the large number of visitors and traffic at the park. A longitudinal study showed that over 10 years the visitor response and assessment of the shuttle service had improved greatly (Mace, Marquit, and Bates, 2013). The continuous feedback between 2000 and 2010 shows that “improvements [in the shuttle service] were greatest for freedom, accessibility, and efficiency”

(Mace, Marquit, and Bates, 2013). However, the public only accepted the mandatory system after the benefits had been carefully designed and well promoted (Mace, Marquit, and Bates, 2013). Like visitors to Acadia, visitors to Zion were first concerned with losing the advantages of using their personal vehicles. Mandatory shuttle services have been adopted less frequently than optional systems as they reduce visitor freedom and inconvenience the elderly, the disabled, and people carrying large amounts of cargo (Mace, Marquit, and Bates, 2013). Furthermore, using mandatory shuttle systems requires the closing of roadways which leads to complaints from local residents who make use of these roads for non-tourist activities (Holding and Kreutner 1998). Because of these effects, local business owners in the Bar Harbor community have been wary of removing cars in the past (Zimmerman, Daigle, & Pol, 2004). The latest reports from park officials indicate that they are searching for a solution that is car-friendly to account for visitor and resident demands (National Park Service, 2016).

Rather than banning personal vehicles, U.S. national parks have tried to encourage alternative modes of travel by implementing intelligent transportation systems (ITS). The deployment of ITS components such as dynamic message signs (DMS) and highway advisory radio (HAR) stations has been successful in disseminating travel information and alleviating congestion. During 2011 and 2013, Rocky Mountain National Park, the most visited park in Colorado, collaborated with the Town of Estes Park to implement DMS and HAR in an attempt to encourage visitors to use the Park-and-Ride shuttle (Villwock-Witte, Eidswick and Miskimins, 2014). DMS displayed short messages about the shuttle information and how to access the HAR station. HAR broadcasted longer messages about road conditions, parking lot capacity, and shuttle services (Collum, 2012). In a survey conducted on Rocky Mountain National Park shuttles, 80% of respondents said that they chose to ride the shuttle because they saw the DMS and 28% of visitors on the shuttle said that they tuned into the HAR station before choosing to take public transport (Collum, 2012). Ninety-two percent of the people who used the shuttle were satisfied with the shuttle service (Collum, 2012). A similar boost in shuttle ridership occurred in Grand Canyon National Park, where usage increased by 30% following the implementation of DMS and HAR (Ye et al, 2008).

Smart solutions to tourist-related traffic congestion

Intelligent transportation systems are becoming increasingly popular as smart ways to mitigate traffic and disseminate real-time data to users. These smart systems are traditionally used in urban environments but are expanding to natural ones. In places like national parks, where tourists crowd the natural land, ITS can boost visitor satisfaction and protect the earth. They have the ability to direct tourists less crowded locations and dissuade off-road parking by promoting other options.

The implementation of ITS to resolve traffic issues has proven to be beneficial to both clients and users. The Seattle Department of Transportation has implemented an ITS to streamline the traffic management process while overseeing transportation throughout the city remotely from their transportation operations center (Seattle Department of Transportation, 2015). This is achieved using infrastructure such as traffic cameras, DMS, and a publicly accessible traffic monitoring website.

Intelligent transportation systems in Acadia National Park

An ITS field operational test was conducted in Acadia from 2000 to 2003 during which nine ITS components were evaluated. The components included in the original plan are displayed in Table 1. The two-way voice communication on the Island Explorer is used for communication between vehicles and the dispatch center. Automatic vehicle locators are used to transmit real-time bus locations. The departure signs compute bus departure time automatically and display this information to travelers at select bus stops. Automated annunciators verbalize next stops to the riders. Passenger counters record the number of passengers getting on and off the bus. Parking lot monitoring systems recorded provided a video feed of the Sand Beach parking lot and Blackwoods Campground. Components associated with automatic ranger/vehicle geo-location compute and relay ranger locations. Entrance traffic volume recorders count the number of vehicles entering and exiting Park Loop Road. A traveler information system disseminates information to travelers; in Acadia, this included the 511 phone system and trip planning website. The implementation of this ITS was incomplete. Automatic ranger/vehicle geo-location and real-time traffic volume recorders were never implemented due to lack of budget and technical difficulties. Although parking lot monitoring and traveler information systems were implemented, they stopped working after the field operational test due to lack of maintenance. Although this ITS was only tested for a short period of time, it was effective. The following statistics were gathered while the original ITS was functional:

- 44% of bus riders said that parking information from the trip planning website influenced their decision to ride the bus (Zimmerman, Coleman, & Daigle, 2003).
- 67% of visitors using private transportation either changed the time they visited a destination or changed their destination entirely (Zimmerman, Coleman, & Daigle, 2003).
- 74% of visitors who saw the parking lot signs in front of Sand Beach and Blackwoods Campground said the information made it easier to get around (Zimmerman, Coleman, & Daigle, 2003).
- 87% of visitors agreed that traffic information such as live bus tracking was valuable or very valuable (Zimmerman and Burt, 2005).

Using current technology, the ITS can be updated and expanded to help Acadia manage traffic problems.

Island Explorer Two-way Voice Communications	Automatic Vehicle Locator for Island Explorer	Departure Sign for Island Explorer
Automated Annunciator for Island Explorer	Passenger Counter for Island Explorer	Parking Lot Monitoring
Automatic Ranger/Vehicle Geo-Location	Entrance Traffic Volume Recorder	Traveler Information Systems

Table 1: Components from the ITS implemented in Acadia National Park in 2002

Any proposed system should take existing components into account and use them to the best of their abilities. For example, in an early report on the feasibility of intelligent transport implementation, it was noted that any solution should encourage more people to use the Island Explorer shuttle as this would reduce the number of cars trying to use park roads (Zimmerman, Coleman, & Daigle, 2003). This system is meant to work in conjunction with private transport since studies have indicated that banning personal cars entirely would be incongruent with visitor preferences (Hallo and Manning, 2009).

As shown in Figure 1, information in an ITS can be collected from parking lot sensors, traffic cameras, car counters, and bus trackers. From there, it is sent to a control center where feeds are autonomously monitored and data is stored. Finally, it is disseminated to tourists via DMS, online video feeds, and mobile traffic and transit apps. It is also collected and monitored by officials for the strategic deployment of staff and long-term data analytics.

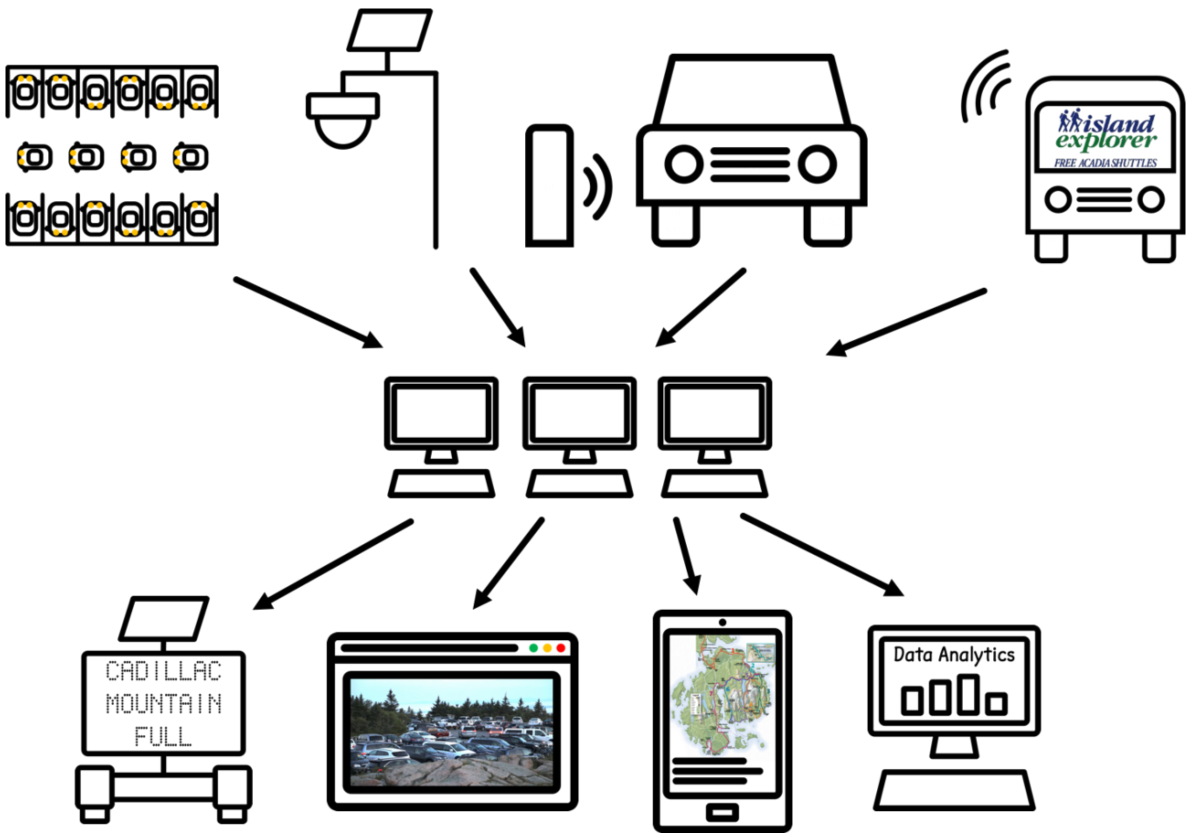

Figure 1: Example components for information collection and dissemination in an ITS

Methods

This project was intended to assist Acadia National Park in addressing the increasing amount of traffic congestion in the park by providing an analysis of the feasibility and implementation logistics of a real-time intelligent transportation system (ITS). The team aimed to achieve the following objectives:

- Evaluate remaining components of the original ITS in Acadia National Park.
- Investigate the capabilities of current ITS technologies.
- Assess the feasibility and logistics of implementing an ITS in Acadia National Park.

The outcomes of the methods described below will be summarized and presented to park officials.

Objective 1: Evaluate remaining components of the original ITS in Acadia National Park

To best understand what new ITS components would be of use in Acadia, an inventory of existing components and their functionality was created. The data for the inventory was gathered online, through first-hand observation, and through consultation with park officials. The inventory checklist was obtained from the park's ITS Field Operational Test Final Report from 2003. The team determined whether or not each component was implemented, presently working, and being utilized by the park. These distinctions were significant because not all components were implemented in the deployment of the original ITS and others had ceased to work properly or were left unused. The assessment of these components was critical to ensure that future ITS recommendations did not ignore past work.

Another aspect of the old system to examine was how well the existing system was promoted in the areas surrounding the park. An important factor in the success of any ITS is how many of the intended users are aware of its existence. At the conclusion of the original ITS implementation in 2003, researchers stated that educating local businesses and enlisting their help to market the system to tourists were necessary steps for the future (Zimmerman, Coleman, & Daigle, 2003). Since an estimated 72% of visitors to Mount Desert Island stay on the island for at least one night, places of lodging have a large role in such marketing to tourists (Manni, Littlejohn, & Hollenhorst, 2009). To determine if these efforts have been made successfully since then, team members visited 70 of the places to stay around Bar Harbor. Each location was checked for visible advertisements about the Island Explorer, the Chimani Acadia app, and the MyStop Mobile app. The Chimani Acadia app is a general information app for the park which includes the Island Explorer bus schedule. The MyStop Mobile app provides visitors with real-time bus tracking and bus passenger counts.

Objective 2: Investigate the capabilities of current ITS technologies

When the inventory of ITS components in Acadia was completed, the team used this list to develop an idea of what new technology would be useful in the park. First, the ITS components that were missing, unused, or broken were identified in the inventory. As shown in Figure 5, the status of a given category suggested the appropriate course of action for those components within. In general, components that were missing or excluded from the original ITS should be implemented. Those that were implemented but not functioning could be fixed or upgraded to newer technologies that were less likely to break and easier to service. Ones that were implemented and functioning were considered for upgrades but generally left to continue operation.

The list of technologies intended to implement, upgrade, or replace old and missing ITS components was used to search for specific providers and solutions. For each type of component, the team identified as many different technologies or companies as possible that fit the requirements of the park. Web searches, case studies, conference proceedings, and advertisements provided leads to a variety of products that met the criteria.

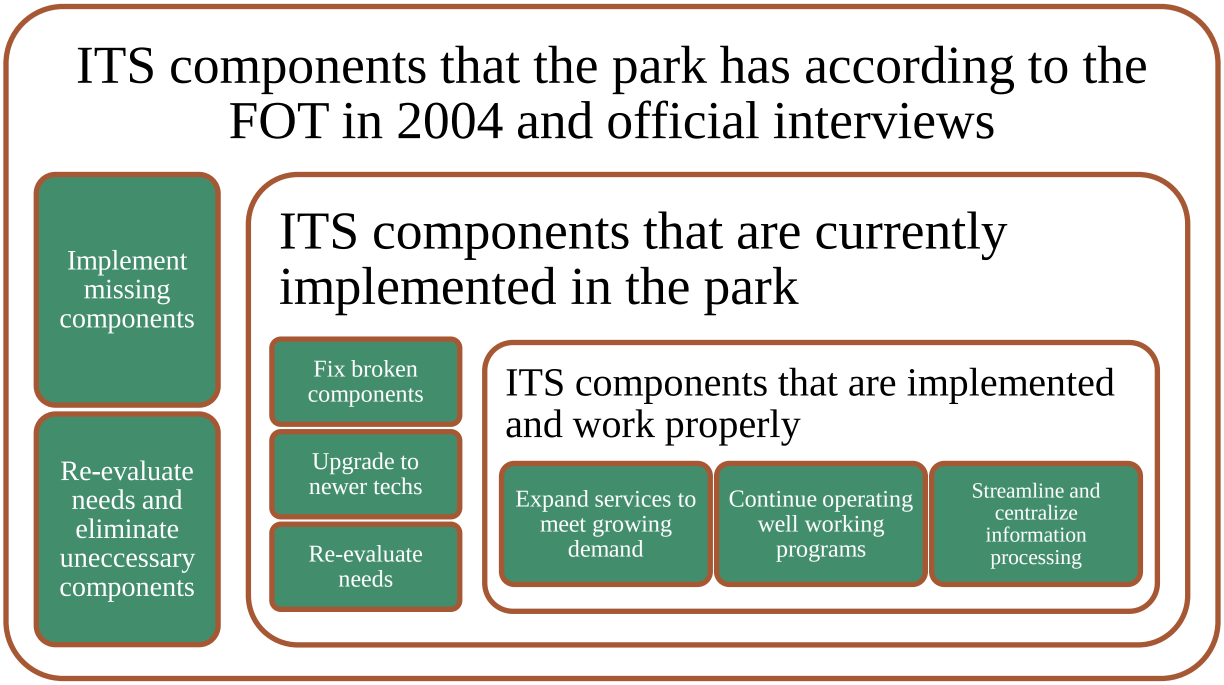

Figure 5: A visual representation of existing ITS in Acadia and how to address the status of each component

Objective 3: Assess the feasibility and logistics of implementing an ITS in Acadia National Park

After a list of possible components was compiled, impractical solutions were immediately ruled out. The remaining possibilities were assessed with the TELOS model in mind. In this model, the technical, economic, legal, operational, and scheduling factors of a potential system are analyzed to assess the challenges of implementation and the value gained from each system. The technical factors of each component are the infrastructure, logistics, specifications, and resources relevant to the component. Economic factors are the financial costs, possible funding sources, and monetary return provided by the system. Legal feasibility pertains to any permits or permissions required to implement a system as well as relevant regulations and contract obligations. The operational feasibility addresses the effectiveness and long-term reliability of the system. Lastly, scheduling factors deal with the amount of time required to implement a component and the amount of time it takes to make a noticeable impact. Based on the categories described above, feasibility criteria were determined. These criteria were used later on to assess different components and make recommendations. This feasibility assessment identified the potential strong and weak areas of each component. It also showed where information about a specific component was missing. If part of a category could not be addressed, it was noted so the team could conduct additional research. Overall, the TELOS model helped the team obtain as much information as possible about each solution and ensure that no important considerations were omitted.

After the TELOS model was used to analyze initial feasibility, a cost analysis for each feasible solution was conducted. ITS companies were contacted to obtain more information about unanswered questions and costs. Customer service representatives provided helpful information that was missing and price estimates for components. The cost analysis provided the final insights that allowed systems to be ranked and categorized as feasible or infeasible.

Results and Analysis

Objective 1: The current deployment of ITS in Acadia

The first objective of this project was to assess and classify the current state of the original intelligent transportation system (ITS) implemented as part of Acadia National Park's Field Operational Test in 2002. Nine components were proposed for the system. Each of the five Island Explorer-related components were designed to make riding the bus an easier, more attractive option, thereby reducing the number of cars on the road. These components included two-way voice communications, automated vehicle location (AVL), real-time departure signs, an automated next-stop annunciator, and passenger counting sensors. The other four components proposed for the ITS were meant to manage traffic issues by providing drivers with information that might influence their decisions and allowing management to monitor conditions in the park. These included parking lot monitoring, automatic ranger/vehicle geo-location, entrance traffic volume recorders, and traveler information systems. The status of the current ITS is shown in Table 4.

Component	Details	Implemented?	Working?	In use?
Island Explorer Two-way Voice Communications	Used for contact between vehicles and dispatch center. Source of traffic information for park staff.	YES	YES	YES
Automatic Vehicle Locator for Island Explorer	Transmits location, integrated with departure signs, website, and annunciator.	YES	YES	YES
Departure Sign for Island Explorer	Computes and displays upcoming departures for riders' information.	YES	YES	YES
Automated Annunciator for Island Explorer	Determines the location and next stop and automatically announces this information to passengers.	YES	YES	YES
Passenger Counter for Island Explorer	Automatically counts boardings and dismounts at stops for planning and data purposes.	YES	YES	YES
Parking Lot Monitoring	Records the number of entering and exiting vehicles, displays video feed to park officials for management	YES	NO	NO

Automatic Ranger/Vehicle Geo-Location	Computes and relays ranger locations for improved deployment and management of rangers and resources.	NO	N/A	N/A
Entrance Traffic Volume Recorder	Records and transmits the number of vehicles entering and exiting for data storage.	NO	N/A	N/A
Traveler Information System	Collects, integrates, and disseminates data to travelers via 511 system, Internet, and parking lot status signs.	PARTIALLY	YES*	YES*

Table 4: The state of existing ITS components in Acadia National Park
(*Indicates that only the remaining bus tracking service works and is in use.)

All five categories of ITS components for the Island Explorer were deployed in 2002 or prior and are still in use now. According to Downeast Transportation, the company that owns and operates the buses, ITS has been used to align the bus schedule with peak tourist season and traffic flow. Many of the ITS components have been updated recently or will be updated in 2018, accompanying the replacement of the current bus fleet. The technical information about each component and a history of any updates performed were obtained through research articles and contact with Downeast Transportation. This information is as follows:

- The two-way voice communication for the Island Explorer utilizes a repeater in the park and radios in each bus. They are used for communications between buses and from buses to the dispatch center. After the original implementation, bus drivers reported that there were some dark areas on the island where they could not receive radio signal. In 2016, the radio system was updated to a higher frequency, which mostly eliminated the issue.
- Passenger counters were installed on each bus and can detect if a passenger is boarding or dismounting the bus. They provide data to help bus managers adjust bus routes during the off-season and cope with increasing demand. This data is also displayed on MyStop; however, the sensors occasionally miscount and display an incorrect number of passengers.
- The AVL for the Island Explorer buses utilizes GPS to compute vehicle location. This information is used to determine if the bus is running early, late, or on time. The locator also transmits the data to departure signs. Finally, the real-time location is transmitted to MyStop every couple of minutes and used by the automated annunciator to notify passengers when the bus is approaching a stop. Very occasional errors with the AVL are

caused by GPS wobble, a rare phenomenon that is unavoidable in this kind of tracking system that causes the sensor to return incorrect coordinates.

- The departure signs are relatively accurate and are located at popular bus stops. Though the departure signs were deployed at only the most frequented locations throughout the park, shown in Figure 6, they have been a key component in encouraging bus usage because long, unpredictable wait times make visitors less likely to ride (Holly, 2009).

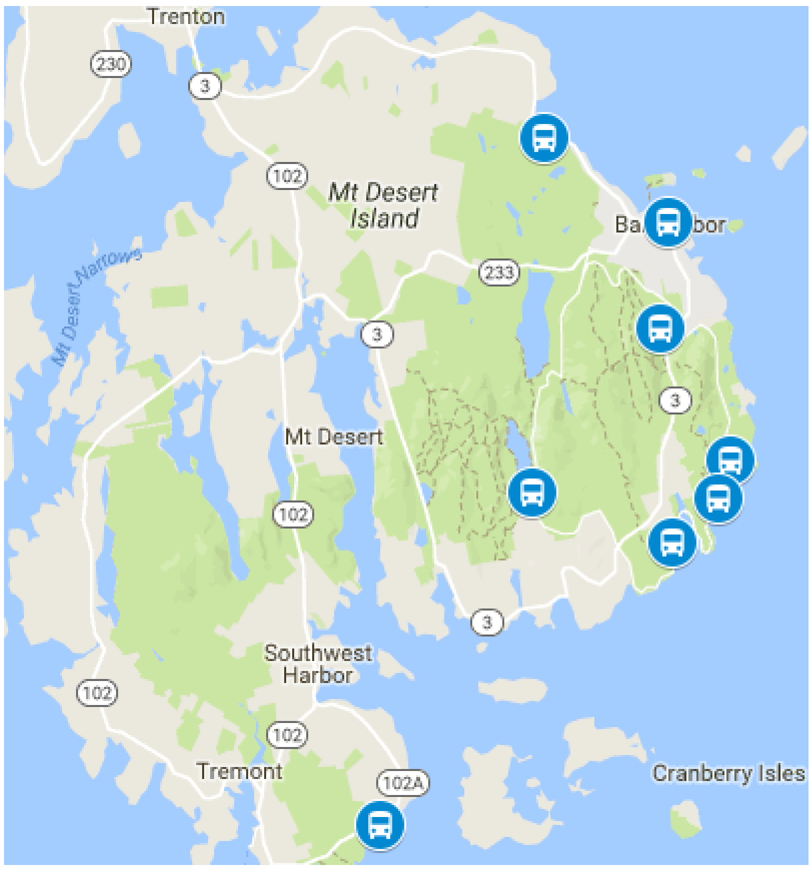

Figure 6: Map of automated departure signs on Mount Desert Island (Map retrieved from Google Maps)

Traffic management solutions have been less successful for various reasons. Due to technical issues and lack of budget, the automatic ranger/vehicle geo-location and the real-time entrance traffic volume recorder were never deployed in the park. While a system for traffic volume recording does exist it does not operate or transmit information in real time and therefore is not considered a component of ITS.

The parking lot monitoring system included video cameras which streamed live feeds to a website and park headquarters. The parking lot monitoring cameras were only installed at Sand

Beach and Blackwoods Campground and required too much staffing and communication to be practical. The traveler information system was only partially deployed; a website showed only the parking lot information for two parking lots. When congestion peaked, static signs were displayed at parking lot entrances stating that the lot was full.

Although the statewide 511 telephone information system was deployed in 2003, it was then moved to newengland511.org in 2016 and no longer has information about Acadia.

While the deployment of parking lot monitoring and traveler information systems was short lived, data collected while the systems were in place show that they had the desired effects. Statistics gathered based on the success of the original system is as follows:

- 44% of bus riders said that parking information from the trip planning website influenced their decision to ride the bus (Zimmerman, Coleman, & Daigle, 2003).
- 67% of visitors using private transportation either changed the time they visited a destination or changed their destination entirely (Zimmerman, Coleman, & Daigle, 2003).
- 74% of visitors who saw the parking lot signs in front of Sand Beach and Blackwoods Campground said the information made it easier to get around (Zimmerman, Coleman, & Daigle, 2003).
- 87% of visitors agreed that traffic information such as live bus tracking was valuable or very valuable (Zimmerman and Burt, 2005).

Promotion of ITS on Mount Desert Island

Of the 70 places of lodging the team examined, 57 had a printed schedule, handout, or posting about the Island Explorer. Most of those places handed out a single-page newsprint bulletin with a map of the bus system and a timetable for each route’s arrivals and departures. These bulletins were also found all around town and made a brief and conspicuous mention of MyStop, the bus tracking service. Thirteen places of lodging had a business card or flyer advertising the Chimani app for general information about Acadia and includes Island Explorer bus schedules. None of the places visited had any information about the MyStop service for real-time bus tracking. Each of these values, shown as a percentage, is shown in Figure 7. Additionally, detailed information about each place visited is located in Appendix A. Since the success of information dissemination relies on visitor knowledge of the tools at their disposal, there is room for improvement in the promotion of the current ITS.

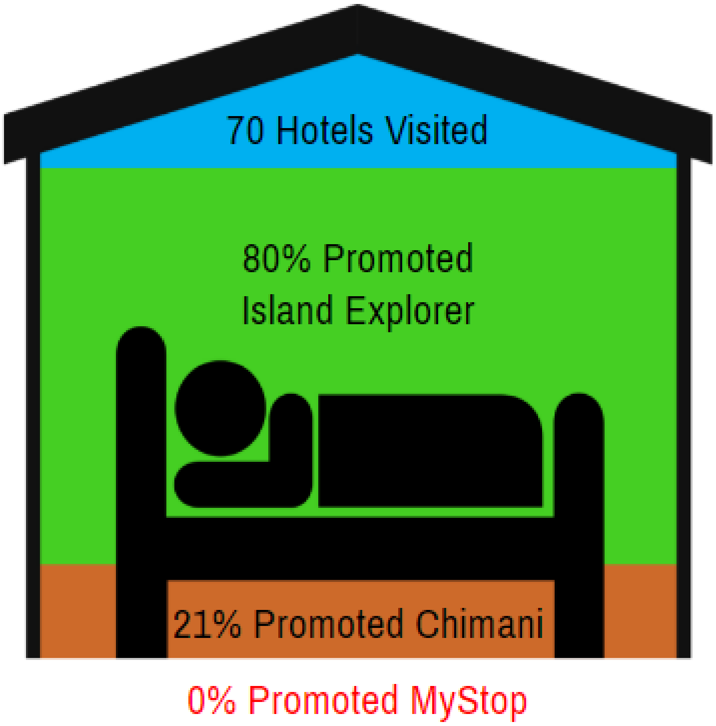

Figure 7: Hotel promotion of traveler information

Objective 2: Capabilities of modern ITS technologies

Since the Island Explorer components were recently upgraded or will be in 2018, they were not considered for upgrades. No new technologies are necessary to enhance the Island Explorer service; rather, the current ITS components for the bus must be promoted more effectively.

The components for parking lot monitoring, ranger/vehicle geo-location, real-time entrance traffic volume recording, and traveler information systems are currently not implemented in the park. Parking lot monitoring was considered a high priority need because it allows for real-time information on congestion in the park. This information allows for smarter decisions when in the hands of tourists, making traveler information systems another high priority. Entrance traffic volume was not considered for upgrades because parking lot monitoring gives similar, more specific information about tourists movements in the park. Ranger/vehicle geo-location was excluded from further consideration in this project because it was not deemed critical for managing tourist traffic.

Data analytics are an important part of modern ITS that was not included in Acadia's original system. Long-term analytics offer many capabilities, of which only a few are currently possible with the non-real-time car counting sensors in place in the park. Because data can be used to help the park make adjustments over time based on concrete trends, this category of ITS technologies was added for consideration.

Parking Lot Monitoring

Parking lot monitoring systems utilize ITS to collect and process information about parking lot status on a real-time basis. The commercially available systems for parking lot monitoring can use a variety of sensors to count the number of vehicles entering and exiting the parking lots and use ancillary software to calculate the number of empty spaces left. Sensors can count cars using infrared, radar, acoustics, pneumatic tube, magnetic field, electric current and video feed. The team found that magnetometers, induction loops, and cameras were the most successful of the car counting devices and focused continued research on these devices.

A magnetometer sensor detects distortions in the local magnetic field when large masses of metal pass by. These sensors are approximately fist-sized and are easy to install. Sensors are either mounted in the roadway or on a post at the side of the road. Commercial magnetometer sensors are enclosed in weatherproof cases to allow them to withstand outdoor environments. The sensors can be powered using existing power lines, batteries, or solar panels. They can transmit data wirelessly via 3G or cellular signal.

Figure 8: Industrial grade magnetometer sensor (Monnit, 2017)

Induction loop sensors detect passing vehicles by way of induction; as a vehicle passes overhead, the change in magnetic field induces an electric current in a loop of wire installed in the roadway and the event is accounted for. They are accurate within 5% of the expected result. The induction loop sensors on the market today consist of the loop itself, an extension cable, and a detector module. The detector module is usually enclosed in a case and mounted near the roadway and distributes power to the loops. To protect the loops from wear and tear, they are insulated and embedded no less than one inch from the road surface. This process makes installation much more difficult and expensive for induction loop sensors compared to other sensors. Their life spans are approximately fifteen years because they have no direct contact with the environment.

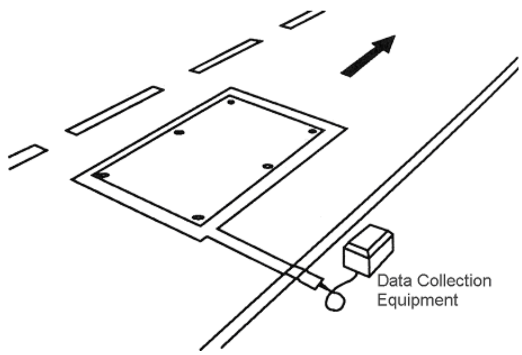

Figure 9: Basic induction loop installation (Diamond Traffic, 2017)

Cameras can also be utilized for parking lot monitoring. Since cameras receive visual information, they require line of sight to every parking space and should be installed on high poles. With the aid of additional video detection software, camera feeds can be analyzed in real time to calculate the current number of spaces available in a lot. Cameras can be powered using existing power lines or solar panels. Collected data can be sent to a central processing software via ethernet or wireless signals. Cameras provide the most detailed information among all the parking lot monitoring sensors. Unfortunately, they are delicate devices that need regular maintenance and the quality of video feeds are easily affected by bad weather such as fog and storms. Furthermore, cameras require a stronger data connection than the other sensors because cameras transmit video which is more data-intensive.

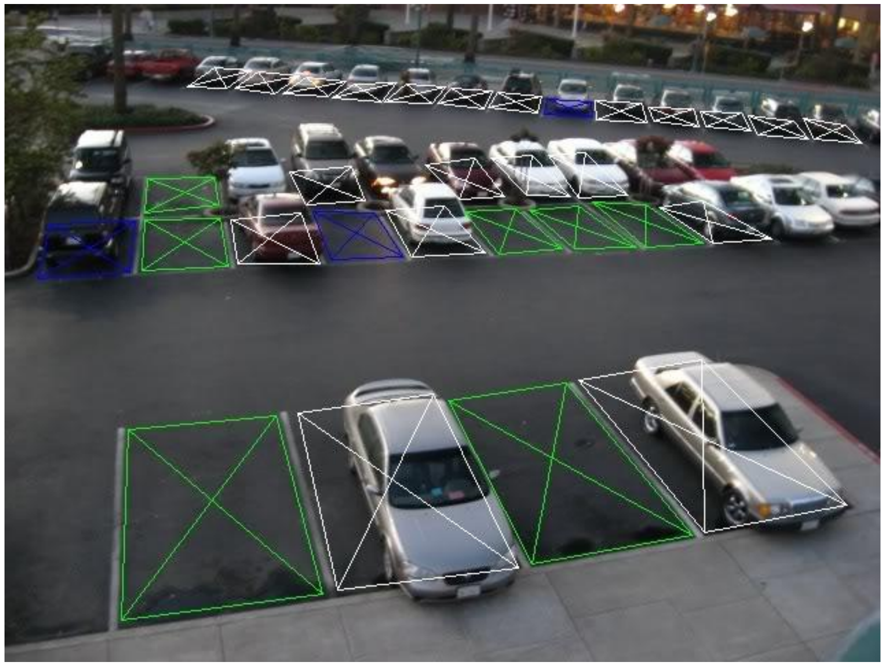

Figure 10: Software processing of camera video feed (AutoDeft, 2017)

Traveler information systems

A traveler information system refers to any media that disseminates real-time information to travelers. Some of the common platforms for disseminating parking information include dynamic message signs, websites and mobile apps.

Dynamic message signs are electronic signs which use LEDs to display information by the roadside. The signs that were investigated display the number of spaces available for multiple parking lots. These are usually large, permanent signs that require hardwired power and data lines. The signs are usually placed a few hundred yards before the parking lots. Permanent signs include a corrosion resistant frame and moisture absorbing material inside to ensure that these signs can tolerate outdoor environments. In Acadia, 74% of visitors agreed that real-time information of parking availability made it easier to get around when the original ITS was functional. By deploying real-time parking availability signs, visitors can better navigate during their trips.

Figure 11: Dynamic parking sign that shows multiple parking lots (Signal-Tech, 2017)

Websites can be added to traveler information systems to display parking data. Combined with general descriptions of tourist attractions, real-time information can be integrated into a trip-planning website. Visitors can access this information before their trip and make plans in advance to avoid crowding and congestion. Additionally, companion apps can be developed to work in sync with websites. Although mobile apps have similar contents as websites, they are accessible wherever tourists bring their phones. Thus, most visitors can check real-time traffic and parking information at any time. One benefit of a companion app would be the ability to obtain real-time information when users have data service and static information when they do not.

Data Analytics

Although the key to ITS is collecting, processing and disseminating information in real time, they can also assist data analytics in the long run. When combined with additional data, such as the date, time, and weather, parking data can be extrapolated to form historical and predictive trends. Results can be provided to managers to anticipate problems. These results can also be integrated into traveler information systems to help visitors make more informed decisions.

Objective 3: Feasibility and logistics of ITS implementation

There are several physical challenges to ITS implementation that make some systems less feasible than others. Due to the mountainous terrain on Mount Desert Island, power and cellular services are big obstacles for the implementation of ITS components. Power lines run to many popular attractions, but many cannot be tapped into to power ITS components. Some locations that would be monitored by ITS lack power altogether. Additionally, although there are commercial cell towers on Mount Desert Island, there are still dark areas where there is no service. Cell tower locations can be found in Figure 12. Lastly, digging and cutting or trimming trees are undesirable requirements for some systems to work. Since the natural aspects of the park are meant to be protected, alternative ways to implement these systems must be found.

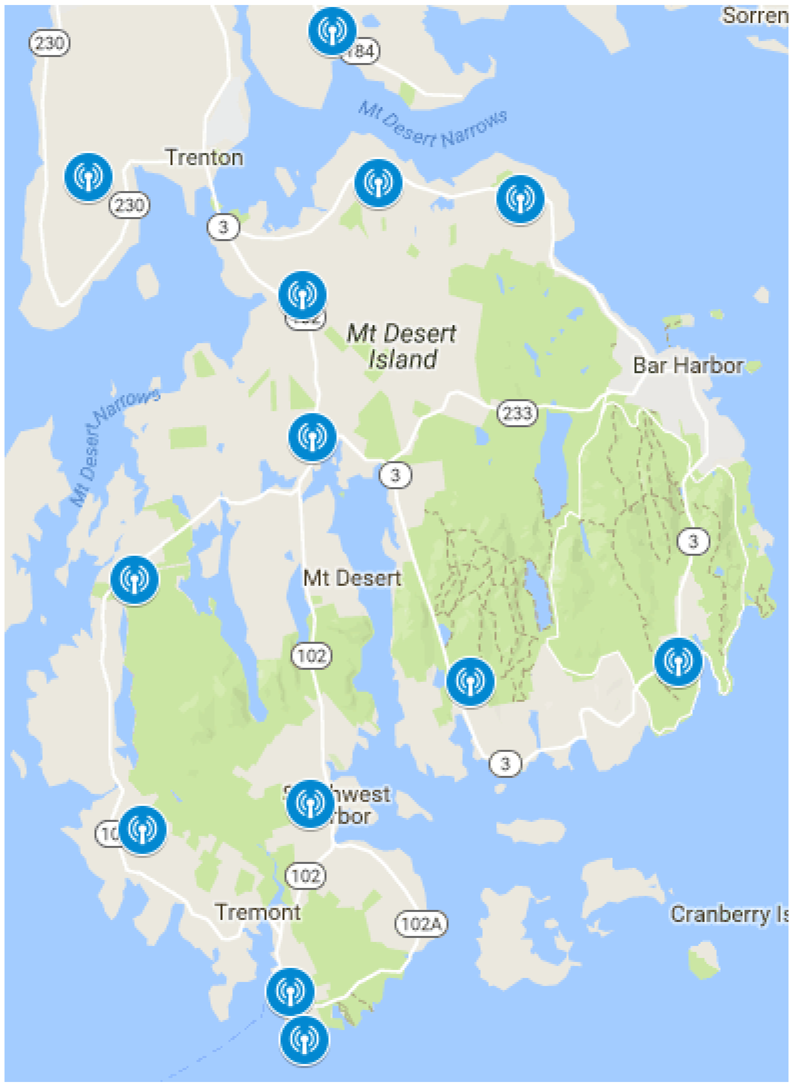

Figure 12: Commercial cell towers on and around Mount Desert Island (Map retrieved from Google Maps)

To establish a baseline metric of the ideal component or system, the following criteria were created according to the TELOS model seen in Table 5. The criteria for each category were created through scholarly research and consultations with park experts. Thus, the TELOS model served as a rubric for the park's needs where all factors were considered.

Category	Ideal qualities
T	The system can be implemented and repaired using existing staff and knowledge at the park. It can be monitored with few or no staff members such that additional people need not be hired to reap the benefits of the system. It does not falter when faced with the challenges of Acadia's geography and can run mostly on existing infrastructure such as radio towers. The system is rugged for inclement weather and runs on low power resources.
E	The equipment is less expensive than similar technologies but still reliable. Any economic returns are perks, but traceable and predictable returns on investment are not expected. If a company offers to sponsor or discount the product in any way, this is a clear benefit.
L	Minimal legal work will be required to install the system. It runs on existing radio frequencies, it does not require special permits to work on wetlands or natural land for installation, and it does not violate any commitments Acadia has to Bar Harbor and the community. Acadia is not bound by an overbearing contract to pay for services related to the equipment and installation will not breach existing contracts with other companies.
O	The system has a clear track record of mitigating traffic problems, perhaps in tourist areas as well as others. Information dissemination to park management and visitors is intuitive and occurs in a variety of ways, from dynamic signs to mobile apps, web interfaces, and a control center for officials to access. The system advises tourists to avoid crowded places and encourages transit use to reduce traffic. The system functions as a deployment tool for rangers and personnel.
S	The system can be implemented in less than a year, preferably during the off-season, and through good promotion, will immediately start to spread out the impacts of traffic in its first season of use. Long-term data analytics will be useful within a few years of data collection, and show a clear trend of improvement.

Table 5: Ideal characteristics of a feasible ITS component in Acadia National Park

Implementation logistics at Sand Beach

Sand Beach was selected for preliminary analysis because of its role in the original Field Operational Test. Since the original ITS in Acadia used a camera at Sand Beach, the team decided that the best first step would be to attempt to monitor that parking lot again with new technology. The logistics below are described in detail for Sand Beach, but can be extrapolated to any destination in the park.

Magnetometer implementation logistics

For Sand Beach, four magnetometer sensors would be required: one for each lane of traffic in and out of each parking lot. Small solar cells can be used to recharge the batteries of each sensor. The cellular access point sold alongside the sensors can receive data from all four of these sensors at once, so only one is necessary. The range between the magnetometers and access point is adequate; the signal can travel up to one thousand feet or more with a line of sight between the sensors and the access point. Thus, the access point can be placed anywhere along Park Loop Road within the vicinity of Sand Beach where there is power and cellular reception. Depending on the cellular provider, there is likely to be basic cell coverage at either Sand Beach itself or at the entrance station, which is within range. As a backup plan, an ethernet access point can be installed at the entrance station, which serves the same purpose but transmits data via a hard-wired internet connection instead of the cellular network. The magnetometer sensors are marketed as rugged and reliable. However, due to their low price, they can be easily replaced. If sensors are replaced on a rolling basis when they become faulty or damaged, the lifespan of the entire system would be indefinite.

The Monnit Corporation provides magnetometers along with all of the necessary components and software to make them work. The parts are sold in an online store where representatives can assist in putting together a complete package. Magnetometer sensors from Monnit cost $220 per unit with a solar panel included. A cellular access point is provided by Monnit with a data plan from one of several providers and is integrated with the sensors. Software from Monnit provides access to online time-stamped data about car counts. It includes an API for development with third parties which Acadia would make use of to disseminate the information about traffic on an external website. This software API would be the gateway between Monnit’s data and a public interface (Monnit, 2017). Installation costs of about $1,500 were estimated based on additional hardware needed to install the system. This includes poles or posts for mounting sensors with all of the associated supplies and costs. The installation cost also includes any potential hardware that might be necessary to purchase from Monnit, such as range extenders for the sensors if the access points must be situated too far away. Exact costs are rather unpredictable but the $1,500 is assumed to cover all potential fees. Lastly, maintenance costs are estimated at $400 annually for a complete system at Sand Beach. If a sensor breaks, replacing it with a new one would be included in the maintenance fee, rather than trying to fix it. Otherwise, this fee covers touch-ups and small fixes that must be made to the system over time such as replacement of posts and screws, or removal of branches that obstruct solar panels. Again, maintenance fees cannot be precisely predicted, but the sensors are rugged and inexpensive so yearly maintenance should not be very costly or elaborate.

Part	Quantity	Unit Cost	Total Cost	Annual Unit Cost	Annual Total Cost
Magnetometer Sensor	4	$220	$880	$0	$0
Cellular Access Point	1	$340	$340	$120	$120
Software Subscription	1	$0	$0	$40	$40
Installation	1	$1,500	$1,500	$0	$0
Maintenance	1	$0	$0	$400	$400
			Total Initial Cost: $2,720		Total Annual Cost: $560

Table 6: Cost analysis of magnetometer sensors (Monnit, 2017)

Induction loop implementation logistics

Induction loops are similar to magnetometers in that one would be required per lane of traffic entering and exiting the parking lots. However, the sensors themselves are large and must be buried underneath the roadway, so excavation, paving, and sealing would need to be done for each of the four lanes. Additionally, poles or posts must be erected at the roadside to hold additional electronics for sensing and communication as well as solar panels for power.

The average cost of an induction loop is only $3,000 per site (John A. Volpe Center, 2011). However, since the installation of induction loop sensors include repaving the roadway, the cost of installation is relatively high. T2 is a company that provides induction loop sensors as a solution to vehicle counting and the costs of one induction loop sensor, its companion software, and its installation is $10,000 (T2 Systems, 2017). Two sets of sensors need to be installed to monitor Sand Beach parking lot, thus the cost would be $40,000. One cellular access point will suffice for data transmission which is estimated to cost about $500 for the hardware and an has annual fee of $120. Although induction loop sensors have a life span of fifteen years and are very unlikely to break, the team estimated the maintenance cost to total of $4,000 per year.

Part	Quantity	Unit Cost	Total Cost	Annual Unit Cost	Annual Total Cost
Induction Loop Sensor Software license Installation	4	$10,000	$40,000	$0	$0
Cellular Access Point	1	$500	$500	$120	$120
Maintenance	1	$0	$0	$1,000	$4,000
			Total Initial Cost: $40,500		Total Annual Cost: $4,120

Table 7: Cost analysis of induction loop sensors (John A. Volpe, 2011)

Camera implementation logistics

A new camera at Sand Beach could be mounted in place of the old one, which has a good line of sight over the whole parking lot and is already mounted on a pole where solar power is available. A second camera for the auxiliary lot would not be able to see the entire lot at once but could be mounted to track cars entering and exiting the parking lot instead. This would require the installation of another pole for mounting with solar panels for power. A cellular access point is required in order to send data to the cloud for aggregation. Software for video analysis needs to be configured and installed on a central computer at Park Headquarters.

Cameras on the market, such as stand-alone cameras from Axis, Honeywell, or Sony, can be used for information collection. The variation of commercial cameras and their qualities leads to a large range of costs varying from $55 for the simplest one to $83,000 for infrared cameras (John A. Volpe, 2011). The cost for one camera at the Sand Beach parking lot and its installation was estimated to be $25,000. If the auxiliary lot is taken into consideration, the cost for two cameras would be doubled. One cellular access point would be required at Sand Beach to transmit data. Since the video collected from the camera contains large amount of information, the cost of the cellular access point is estimated to be $500 with an additional data plan of $120 per year. The team consulted TrafficVision which is a company that aims to provide real-time traffic information by analyzing video streams. The software needs to be configured and costs about $2,000 per camera per year (Traffic Vision, 2017). The estimated maintenance fee is $2,500 for each camera per year (John A. Volpe, 2011). As a result, the camera-based system for Sand Beach would cost $25,500 initially with an annual fee of $4,620. Should the system include the auxiliary parking lot, the initial cost would be raised to $50,500 and the annual cost would be raised to $9,120.

Part	Quantity	Unit Cost	Total Cost	Annual Unit Cost	Annual Total Cost
Camera Installation	2	$50,000	$50,000	$0	$0
Cellular Access Point	1	$500	$500	$120	$120
Software Subscription	2	$0	$0	$2,000	$4,000
Maintenance	2	$0	$0	$2,500	$5,000
			Total Initial Cost: $50,500		Total Annual Cost: $9,120

Table 8: Cost analysis of cameras (John A. Volpe, 2011)

Traveler information systems implementation logistics

A permanent, customized dynamic message sign could be placed near the Sand Beach entrance station showing the number of available spaces in parking lots around Park Loop Road. The sign must be positioned several hundred feet after the entrance station to give drivers ample time to make a decision before they reach Sand Beach. The sign can be powered by the entrance station and data can be transmitted using ethernet cable. The cost of a permanent LED changeable message sign ranges from $4,000 to $283,000 (John A. Volpe, 2011). For a sign large enough to display counts for several parking lots, the team estimated the cost to be $100,000 with an annual maintenance cost of $5,000.

An integrated, centralized website for travel and trip planning would be the best way to adjust visitors' behavior before and during their visits. The mock-up shown in Appendix B, Figure 14 includes some of the most important features such a website would include. The site could have internal pages for trip planning and parking lot information, as well as links to external services such as MyStop for bus tracking and exploreacadia.com for details about the Island Explorer. A website would also be an important promotional tool. Important keywords like “See more...on the free Island Explorer,” “reduce stress,” and “simplify parking” are derived from research about encouraging visitors to use ITS (Collum and Daigle, 2015). These words are all emphasized on the homepage, as seen in Appendix B, Figure 15. A traffic forecast system where destinations are assigned a color based on their predicted traffic situation on a given day would make use of historical data. Drop-down menus would give a more broken down prediction for each location, as shown in Appendix B, Figure 16. The website could have responsive design so that it is easy to use on mobile devices. Figure 17 shows the mock-up web page in a mobile browser window. Additionally, a mobile application could be created with the same look and feel of the website so that information can be easily accessed across multiple devices. A mobile application would be able to provide users with mobile, real time data as long as they have cellular service and static data when they do not.

Results from data analytics could also be integrated into the website. For example, graphs showing parking availability trends from the past 24 hours as well as the prediction for the next 24 hours, as shown in Appendix B, Figure 18. Weather information can also be added to refine the prediction. The sidebar showing the weather forecast could help visitors make better decisions. This forecast could be updated with helpful advice based on correlations between weather and traffic. Data analytics for both park managers and visitors would come from the software provided with the parking lot sensors.

One-time development fees for both a website and a mobile app would roughly total $220,000. No annual fees are included because the only required upkeep would be data inputs from park staff. Also, the design is assumed to last for five to ten years after development before an update would be desired. A server that could handle the volume of web traffic from the website and the app would cost approximately $25,000 each year. Server space would be provided off-site by a third-party company so that minimal technical knowledge or setup is required.

Part	Quantity	Unit Cost	Total Cost	Yearly Unit Cost	Yearly Total Cost
Dynamic Parking Sign	1	$100,000	$100,000	$0	$0
DMS Maintenance	1	$0	$0	$5,000	$5,000
Website	1	$150,000	$150,000	$0	$0
Mobile App	1	$70,000	$70,000	$0	$0
Server Hosting	1	$0	$0	$25,000	$25,000
			Total Initial Cost: $320,000		Total Annual Cost: $30,000

Table 9: Cost analysis of traveler information systems

Recommendations

The recommendations detailed below are divided into two subgroups: a selection of ITS components with implementation logistics and a few suggestions for improving ITS as it currently exists in the park. Recommendations for ITS components are based on the results of the TELOS model and a cost analysis. Suggestions for ITS improvements are based on research done in Acadia and the surrounding communities.

The team’s most favorable recommendation to the park was a magnetometer-based system. Should this plan be implemented, each magnetometer would be mounted at engine block height facing an individual lane at every location. Magnetometers would count cars entering and exiting the lots; this information would then be broadcasted back to park headquarters and displayed on signs far enough ahead of parking lot turn-offs to allow visitors to make informed travel decisions. The same information would also be uploaded to a website to inform visitors of historical and real-time parking conditions before they embark for the day. Magnetometers became the team’s first recommendation because of their ease of installation, relatively low cost, and seven year lifespan. This system can be installed by park staff and runs autonomously. Additionally, the sensors are rugged and would run off-grid with low power. Magnetometers are packaged with all hardware necessary for installation with the exception of poles and are designed to be incredibly simple to install. The team viewed these traits as extremely favorable because they would reduce installation costs by eliminating the need for an outside contractor. The initial cost calculated for this recommendation was $2,720 with an annual cost of $560 for implementation at Sand Beach.

If magnetometers were deemed to be inadequate by the park, the team’s second recommendation was an induction loop-based system. Induction loops are similar to magnetometers in the way that they count cars but are significantly more expensive. An induction loop is a loop of wire that is embedded in the roadway. As cars pass over the loop, the magnetic field is disturbed by the car inducing a current in the loop; this event is then accounted for within a post-mounted counter beside the road. Similar to the magnetometers, induction loops can send data to be broadcasted on dynamic message signs and websites. Since induction loops are already in use in several parts of the park, management is familiar with their installation and maintenance. Induction loops come second to magnetometers because the installation for each unit is much more expensive but not much more beneficial, even when taking into account that the lifespan of an induction loop setup is twice that of a magnetometer setup. The calculated initial cost for implementation of an induction loop system at Sand Beach totalled $40,500 with an annual cost of $4,120.

A camera-based solution was the third and final recommendation that was presented to the park. With the right software, cameras would be able to provide a video feed as well as video analytics that can count the number of available spaces. While cameras would be able to provide a visceral idea of the extent of overcrowding, they are also the most expensive option and must overcome several obstacles that are particularly difficult to handle in a natural area. Because cameras are sight-based, complications such as trees, fog, and irregularly shaped parking lots pose unique challenges. It is for these reasons that cameras were the least desirable system to be recommended. The initial cost for a camera-based system at Sand Beach totalled $25,500 with an annual cost of $4,620 or an initial cost of $50,500 with an annual cost of $9,120 if a second camera is installed to monitor the smaller, auxiliary parking lot at that location.

In addition to each sensor recommendation, the team suggested that dynamic message signs should be placed at an appropriate distance before each monitored parking lot entrance to display real-time space availability. A sign placed soon after the Park Loop Road entrance station could display space counts for the nearest few monitored lots. Dynamic message signs would be beneficial because they would provide visitors with real-time data immediately before approaching their destination. A custom sign displaying multiple parking space availability counts was estimated to cost $100,000 with $5,000 annual maintenance.

One of the most crucial components of the team’s proposal was a comprehensive parking and travel data website. A website could include historical and predictive data to give visitors an idea of how difficult it may be to find parking in various locations. Such information has been proven to convince visitors to take the Island Explorer, change their destination, or change the time they choose to visit their original destination. Because the internet is an ever-expanding resource that is available to almost every visitor to the park, a website would provide a key opportunity for disseminating travel-oriented information to those who can take advantage of it. An advanced trip planning website was estimated to cost $150,000. Server hosting would cost about $25,000 annually.

In addition to a website, a companion mobile application with a similar look and feel could be created so that the same information would be easily accessible across multiple devices. The application would serve the same purpose as the website but would be formatted for mobile devices; it could provide real-time information when visitors have cellular data service and static information when they do not. A companion application was estimated to cost $70,000 and could share the server for the trip planning website.

Software for analytics would be included with any of the recommended systems and is crucial to reap the benefits of ITS. Analytics could provide parking data, turnover rates, peak times, weather-based predictions, advanced warning, and carrying capacities for each monitored location. Any analytic software would also function autonomously to minimize the time and effort required by park staff to utilize the information.

Perhaps the most essential piece of the team's recommendation was for the park to adequately promote existing infrastructure and any newly implemented technology. Counting open parking spaces will never influence visitor behavior unless that information is disseminated properly, and the disseminated information is useless if visitors are unaware of its existence. The proposed website should advertise the Island Explorer and use research-based keywords and concepts to convince visitors to take advantage of available services.

Though the team's recommendation was limited to the pilot location of Sand Beach, several other attractions throughout the park could benefit from the implementation of ITS components. After the implementation of ITS at Sand Beach, results should be observed. If the new ITS proves effective in monitoring and mitigating congestion, the park should expand the system to other locations. The team recommends that the Cadillac Mountain parking lot is next to be monitored so that park staff can remotely monitor the crowding that often reaches dangerous levels. Jordan Pond House is another extremely popular location that can benefit from the implementation of an ITS. The Visitor Center parking lot would follow since visitors are encouraged to go there but space is limited. These locations are identified in Figure 13. Because the infrastructure such as dynamic parking signs, a website, a mobile app and data analytic software will have already been implemented, each expansion only requires additional hardware installation. Visitors will have grown accustomed to utilizing the system at Sand Beach, and will be accepting and welcoming of its expansion.

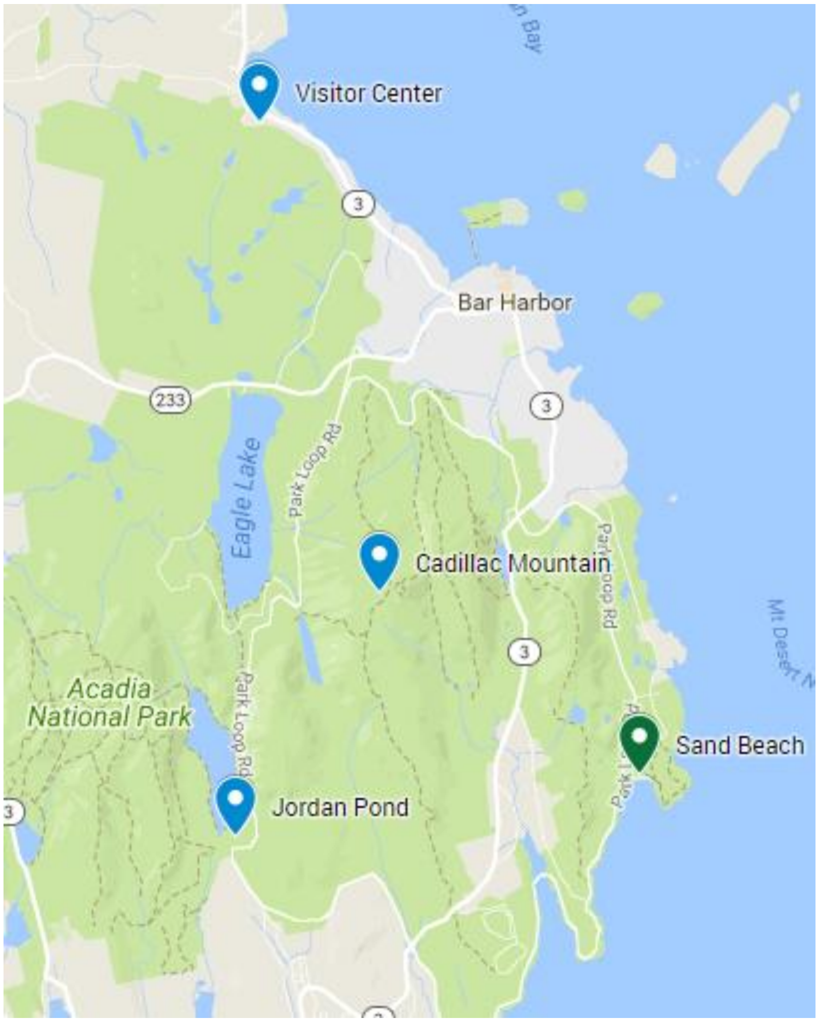

Figure 13: Future locations for ITS implementation (Map retrieved from Google Maps)

Conclusions

In this report, the feasibility of implementing an intelligent transportation system in Acadia National Park was assessed and logistics for installation were discussed. The key features of the recommended system are parking lot monitoring sensors, dynamic message signs, an online traveler information service, and data analytic software. It was found that magnetometers would be the most effective parking lot sensors in Acadia since they are the most cost-effective and easiest to install of the components considered. Logistically, these sensors require minimal new infrastructure since they are completely wireless. Dynamic signs are much more costly and will likely require physical cabling for power and data, but these signs would be very helpful to park visitors. A mock-up web service for trip planning in Acadia was designed by the team to showcase what features and keywords must be used to change visitor behavior based on research. An app would be developed alongside the website to give mobile users easy access to information at all stages of their trips. Lastly, data analytics would provide historical trends and future predictions to park managers and visitors alike. It was determined that Sand Beach was the optimal location to pilot the physical components of a system, while Acadia should have a central online platform for travel information as soon as possible. If the system is successful in its initial years, expansion to other notoriously crowded areas will be easier because of the precedent set for installation, software, and third-party contracting.

From this project, it was concluded that intelligent transportation systems have an important role in keeping Acadia park open to the increasing number of tourists who visit each year. When all of the proposed ITS components are working together in a system, visitors to the park will be able to make better decisions about how to plan their trips. Managers will be able to anticipate overcrowding problems before they arise. These benefits will make Acadia more accessible and easier to navigate for everyone. The long-term effects of such a system are less environmental damage and greater levels of visitor satisfaction. Adjustments to travel in the park can be made based on concrete data and trends. While an overwhelming amount of technology in our daily lives might be why countless tourists seek the natural solace of Acadia each year, the technology is destined to follow them there. Without an ITS, access to the beauty of the park might have to be restricted in future years because current means cannot effectively manage traffic. Although the creators of ITS technologies probably did not envision their inventions solving traffic problems in national parks, the need for data analytics and traffic redistribution dictates the use of technology. In a world that is increasingly connected, even parks must adapt to make the most of the information age.

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Appendix A: Hotels that promote ITS

Hotels, motels, and inns around Bar Harbor and the northeastern side of Mount Desert Island were visited to examine how they promote ITS components. Only the results from the places visited are tabulated below. Places that were not visited were excluded from the table.

Location	Address	IE Brochure?	IE General?	MyStop?	Chimani?
Bar Harbor Grand Hotel	269 Main St	Yes	Yes	No	Yes
Atlantean Cottage B&B	11 Atlantic Ave	Yes	Yes	No	No
Snell House	21 Atlantic Ave	No	No	No	No
Bar Harbor Villager Motel	207 Main St	Yes	Yes	No	No
Moseley Cottage Inn and Town Motel	12 Atlantic Ave	Yes	Yes	No	No
Shore Path Cottage, Bar Harbor Bed & Breakfast	24 Atlantic Ave	Yes	Yes	No	No
Balance Rock Inn	21 Albert Meadow	Yes	Yes	No	No
Ivy Manor Inn	194 Main St	Yes	Yes	No	No
Acadia Hotel - Downtown	20 Mount Desert St	Yes	Yes	No	No
Seacroft Inn	18 Albert Meadow	Yes	Yes	No	No
Yellow House Bed & Breakfast	15 The Field	Yes	Yes	No	Yes
Bass Cottage Inn	14 The Field	No	No	No	Yes
Ullikana Inn	16 The Field	Yes	Yes	No	No
Bar Harbor Inn	1 Newport Dr	Yes	Yes	No	Yes
West Street Hotel	50 West St	No	Yes	No	No
Harborside Hotel	55 West St	Yes	Yes	No	No
Manor House Inn	106 West St	No	Yes	No	No
The Central House	60 Cottage St	Yes	Yes	No	No
Acacia House	6 High St	Yes	Yes	No	No
Hearthside Inn	7 High St	Yes	No	No	No
The Maples Inn Bed & Breakfast	16 Roberts Ave	No	Yes	No	Yes

Aysgarth Station	20 Roberts Ave	Yes	Yes	No	Yes
Thornhedge Inn	47 Mt Desert St	Yes	Yes	No	Yes
Anchorage Motel	51 Mt Desert St	Yes	Yes	No	No
Anne's White Columns Inn	57 Mt Desert St	Yes	Yes	No	No
Stone Throw Cottage Inn	67 Mt Desert St	Yes	Yes	No	No
Mira Monte Inn	69 Mt Desert St	Yes	Yes	No	No
Mount Desert Street Motel	68 Mt Desert St	Yes	Yes	No	No
Holbrook House Bed & Breakfast	74 Mt Desert St	Yes	Yes	No	Yes
Primrose Inn	73 Mt Desert St	Yes	Yes	No	Yes
Primrose Place	51 Holland Ave	Yes	Yes	No	Yes
Quality Inn	40 Kebo St	Yes	Yes	No	Yes
Bar Harbor Manor	47 Holland Ave	No	Yes	No	No
Castlemaine Inn	39 Holland Ave	No	No	No	Yes
The Elmhurst Inn	40 Holland Ave	Yes	Yes	No	No
Holland Inn	35 Holland Ave	Yes	Yes	No	No
Quimby House Inn	109 Cottage St	Yes	Yes	No	No
Saltair Inn	121 West St	Yes	Yes	No	No
Wonder View Inn	50 Eden St	Yes	Yes	No	Yes
Hampton Inn Bar Harbor	12 Norman Rd	No	No	No	No
Atlantic Eyrie Lodge	6 Norman Rd	Yes	No	No	No
The Bluenose Inn	90 Eden St	Yes	Yes	No	No
Cleftstone	92 Eden St	Yes	Yes	No	No
Highbrook Motel	94 Eden St	Yes	Yes	No	No
Edenbrook Motel	96 Eden St	Yes	Yes	No	No
Bar Harbor Motel	100 Eden St	Yes	Yes	No	Yes
Days Inn Bar Harbor	120 Eden St	Yes	No	No	No
Holiday Inn Resort Bar Harbor	123 Eden St	Yes	Yes	No	No
The Colony Cottages	20 ME-3	Yes	Yes	No	No

Gallagher's Travels Motel & Cabins	122 ME-3	Yes	Yes	No	No
Hanscom's Motel	273 ME-3	Yes	Yes	No	No
Hinckleys Dreamwood Cottages	318 ME-3	No	Yes	No	No
High Seas Motel	339 ME-3	Yes	Yes	No	No
Acadia Pines Motel	389 ME-3	Yes	Yes	No	No
Robbins Motel	396 ME-3	Yes	No	No	No
Emery's Cottages On the Shore	181 Sand Point Rd	No	Yes	No	No
Best Western Acadia Park Inn	452 ME-3	Yes	Yes	No	No
Bay Meadow Cottages	126 Old Bar Harbor Rd	Yes	Yes	No	No
Bar Harbor Cottages & Suites	144 Old Bar Harbor Rd	Yes	Yes	No	Yes
Woodland Park Cottages	3 Woodland Loop	Yes	No	No	No
Coach Stop Inn Bed and Breakfast	715 ME-3	Yes	Yes	No	No
Rose Eden Cottage	864 ME-3	Yes	No	No	No
Hadley's Point Campground	33 Hadley Point Rd	Yes	Yes	No	No
Belle Isle Motel	910 ME-3	Yes	Yes	No	No
Heathwood Inn	6 Long & Winding Rd	No	No	No	No
Mt Desert Narrows Camping Resort	1219 ME-3	Yes	Yes	No	Yes
Sunnyside Motel & Cottages	1441 ME-3	Yes	Yes	No	No
Bar Harbor / Oceanside KOA	136 County Rd	No	No	No	No
Windward Cottages	28 Western Bay Rd	Yes	Yes	No	No
Seaside Cottages On the Shore	1500 ME-102	Yes	Yes	No	No

Appendix B: Mock-up travel website

The following web pages were created by the team as a mock-up centralized travel platform to showcase the most important features such a website should have.

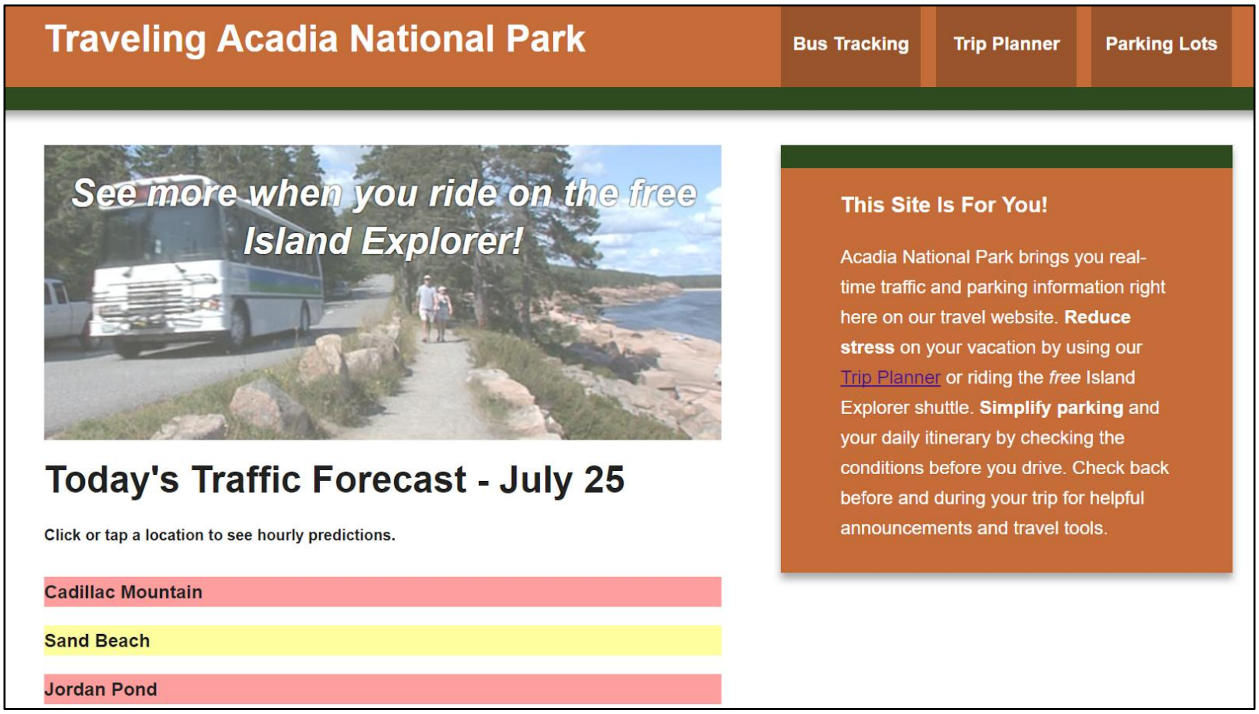

Figure 14: Mock-up travel website homepage

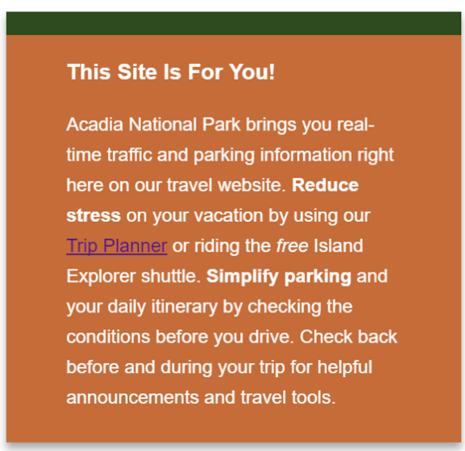

Figure 15: Close-up of homepage sidebar

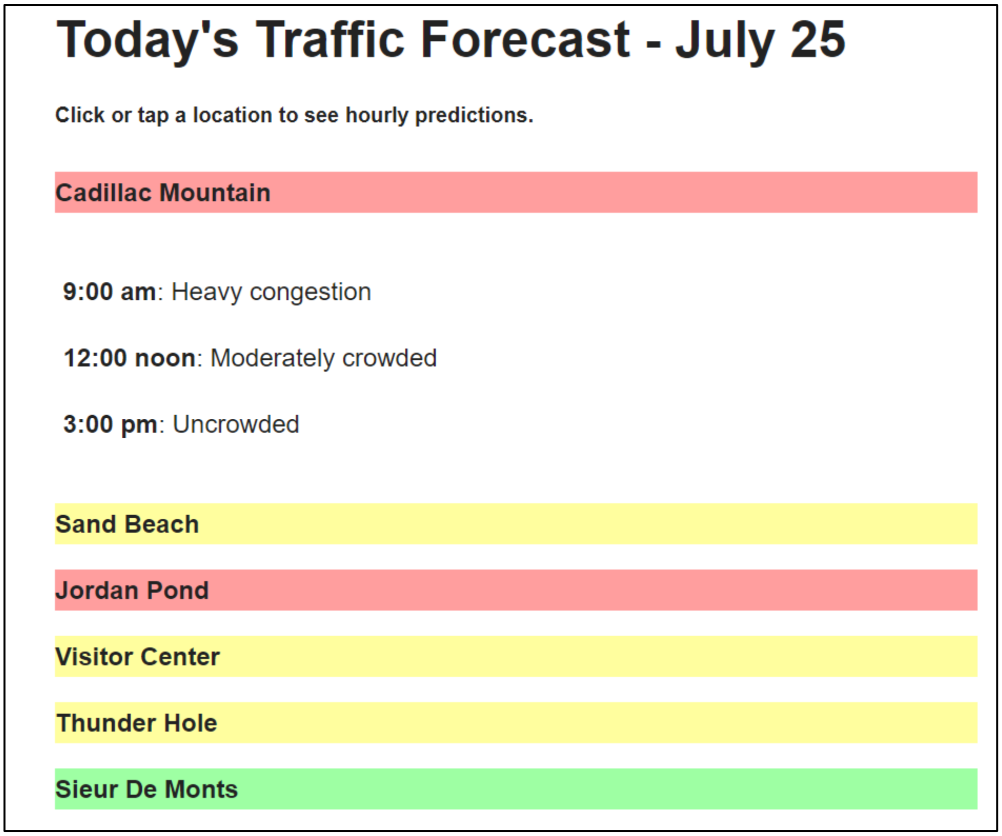

Figure 16: Close-up of traffic forecast with drop-down information

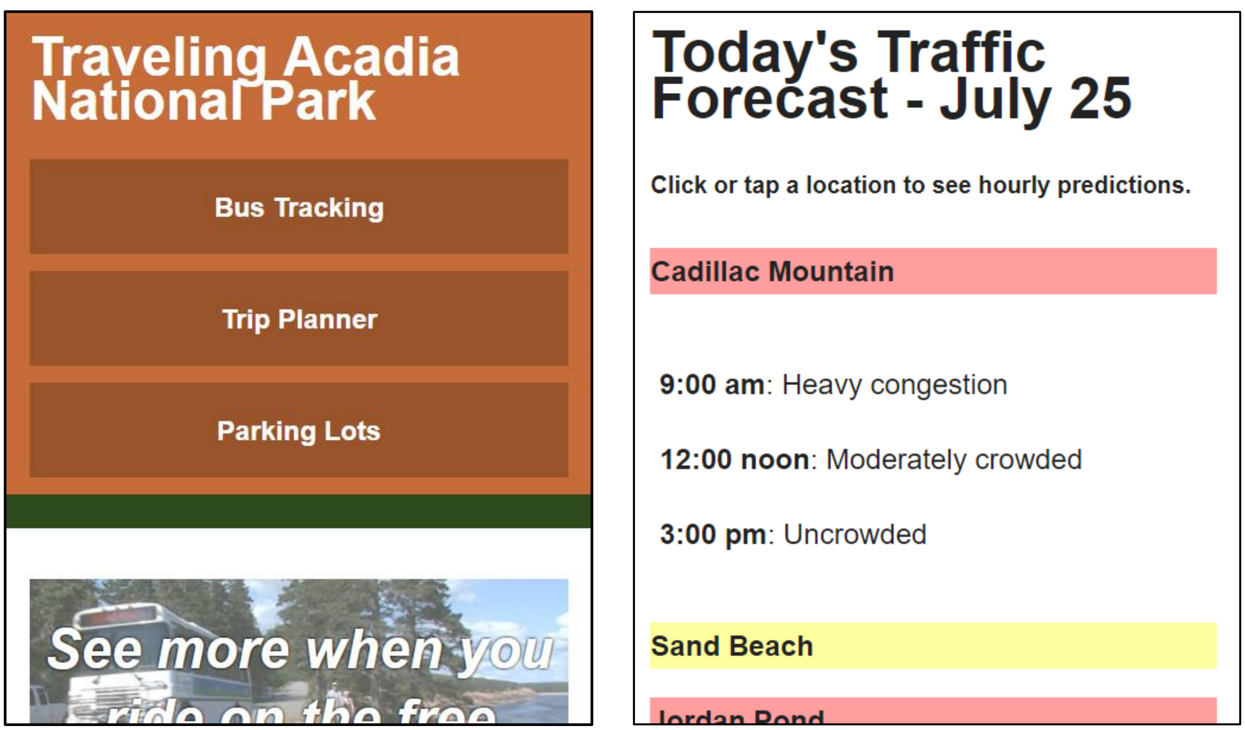

Figure 17: Responsive design of the mock-up website

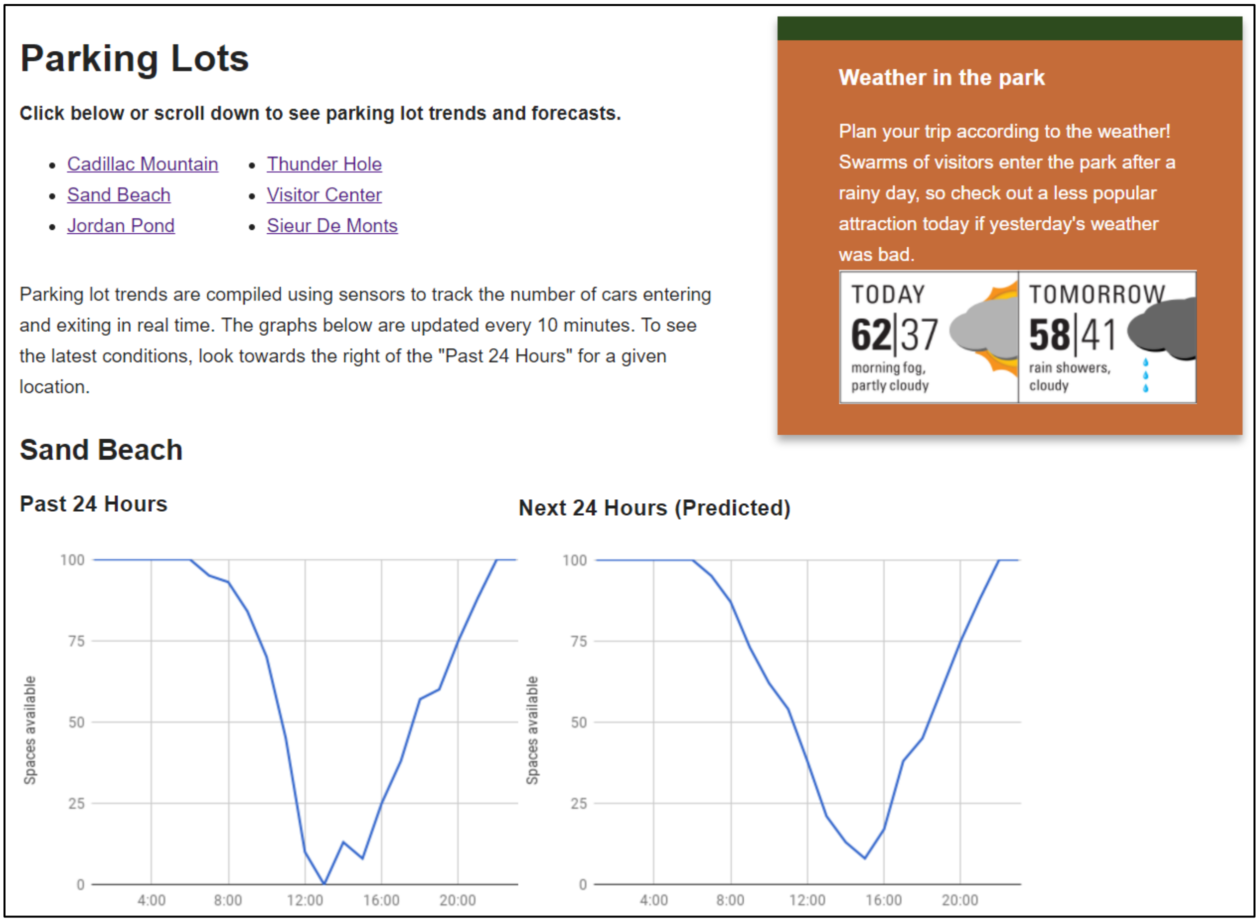

Figure 18: Mock-up parking information webpage