Visitor Tracking in Glacier National Park

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Development of a Visitor Tracking Phone App: To Gain a Better Understanding of Visitor Mobility and Behavior

An Interactive Qualifying Project
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degree of Bachelor of Science

by
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ABSTRACT

In order to have a better understanding of visitor congestion issues in Glacier National Park, a GPS tracking mobile phone app was designed to be distributed to park visitors. The app was designed to collect a GPS data point every 15 seconds, upload the data to a server, and then delete the data from the phone. With collected GPS data more information about visitor mobility and behavior in the park can be determined. Over time, using Big Data strategies, extensive GPS data can be collected and analyzed with predictive analysis techniques to expose unintuitive patterns in visitor mobility and behavior. Finally, the team recommends that Glacier National Park collaborate with an existing third-party company to develop the extensive data processing and analysis components of the application.

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EXECUTIVE SUMMARY

Over recent years, the number of visitors going to the National Parks has increased, causing more congestion issues within the parks. The parks are currently unable to accommodate the increased visitation, causing many attractions and points of interest to fill up quickly. With more visitors, it is difficult for the parks to preserve the national landscapes. These issues are prominent at Glacier National Park, especially along Going-to-the-Sun Road, the only road that traverses the park.

The project addresses congestion issues in Glacier National Park by developing a mobile phone app that captures GPS information from park visitors. Because the mobile app captures GPS location every 15 seconds and gives it a time-stamp, the app can help park management better understand visitor mobility and behavior in the park. By using collected data from the application, staff will be able to know the exact movements of visitors during their time in the park. This information may provide park staff with a better understanding of congestion issues within the park.

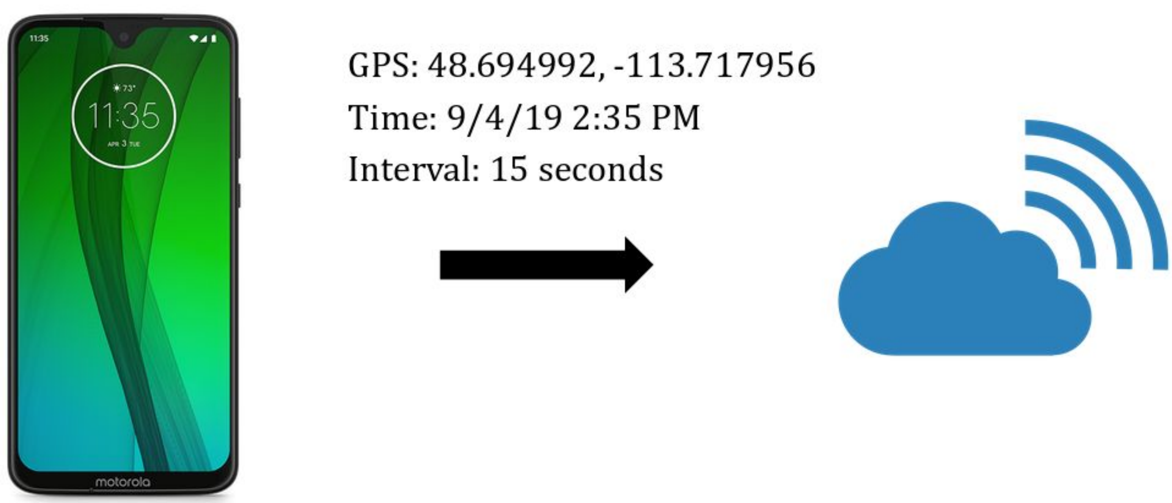


Figure 1: GPS Collection Flowchart. Screenshot by Jason Jemison, 2019, containing images reprinted from *pixelprivacy.com* and *motorola.com*.

Glacier has already taken steps to gain a better understanding of visitor mobility and behavior. They are currently using car counters at 7 locations in the park to count the number of cars entering. However, car counters can not address the issues of how visitors move about the park or how they behave. In the proposed mobile app, the collected GPS data can be used to accurately track a visitor's precise mobility and behavior while moving about the park.

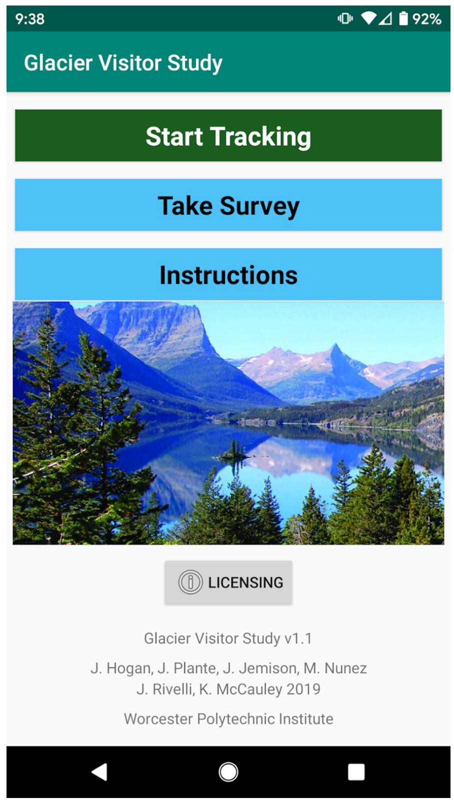


Figure 2: Screenshot of Glacier Mobile Application. By Mara Nunez, 2019.

While in Glacier National Park, the mobile application was developed and distributed to 10 students from the Worcester Polytechnic Institute (WPI). A server, hosted by WPI, was used to collect and store the GPS locations and associated time stamp from the phone. After collecting sufficient data points from the students, ArcGIS Online was used for data visualizations. Due to the time stamped data, the visualizations made with ArcGIS Online could differentiate between hiking, biking, driving, and stops made around Glacier. This method of data collection proved to be a viable way to understand visitor mobility and behavior.

At the conclusion of the project, a recommendation was made to park staff. In order to continue the development of the visitor tracking app, a partnership with an existing mobile app company should be pursued. Companies such as Chimani, OnCell, and REI Co-op have applications that already track users by determining their GPS location and time stamp. However, these companies do not store the GPS and time stamp location. Instead, this data is deleted from the phone when the user finishes. A partnership with a third-party developer would need to address the issues associated with developing a large database of user information and storing it on an off-site server. Once on a server, the data would be available for a variety of analysis strategies and Big Data exploration.

CHAPTER 1: INTRODUCTION

There is a traffic congestion problem within the National Parks. Since 2013, there has been a more intense rising trend in the number of visitors to Glacier National Park, making it the tenth most visited National Park in the United States. In 2017, the number of visitors peaked at about 3.3 million, with over one million in July alone. This made July the busiest month in the park's history (National Park Service, 2019). Likewise, the large increase of visitors leads to congestion problems in Glacier and other national parks. These congestion problems are easily seen during the parks' peak seasons, which for Glacier is from June to September (National Park Service, 2017).

The most popular attractions in Glacier are along The Going-to-the-Sun Road, which is the only road that traverses the entire park. At the three visitor centers along the road, Apgar, Logan Pass, and St. Mary, parking lots fill up very early in the day, meaning visitors entering the park mid-day have a low chance of finding a parking spot (Glacier National Park, 2019). The points of interest along Going-to-the Sun Road cause traffic back-ups as people stop at pull-offs that have already filled up, forcing people to drive around them, blocking opposing traffic. Some other problematic areas experiencing congestion issues are Many Glacier and the North Fork. These sites often experience unexpected closures due to overflow traffic and day hikers. This is especially inconvenient to those who have reservations for lodging or activities in these locations (Glacier National Park). Congestion can be hard to manage as 'un-plugging' one area of congestion may affect another area of the park resulting in a bottleneck elsewhere.

During recent years, Glacier has been taking steps to mitigate congestion issues within the park. These actions include expanding shuttle service hours, adding more parking spots, and making some trails one-way. Shuttle service hours are planned to be extended from 6:30am to 9:00pm with more stops added along the Going-to-the-Sun Road (Glacier National Park). Some of the more drastic solutions include timed entry permits at entrances and parking permit systems for the more popular sites.

To better understanding visitor mobility and behavior within the park, a mobile tracking application was developed. The application tracks visitor's movements while traveling throughout Glacier National Park. The application collects the user's GPS location every 15 seconds and uploads that data to a server for storage. This allows for a wealth of knowledge on where people are going, how they are getting there, and the duration of travel times. The GPS data can then be further analyzed for trends.

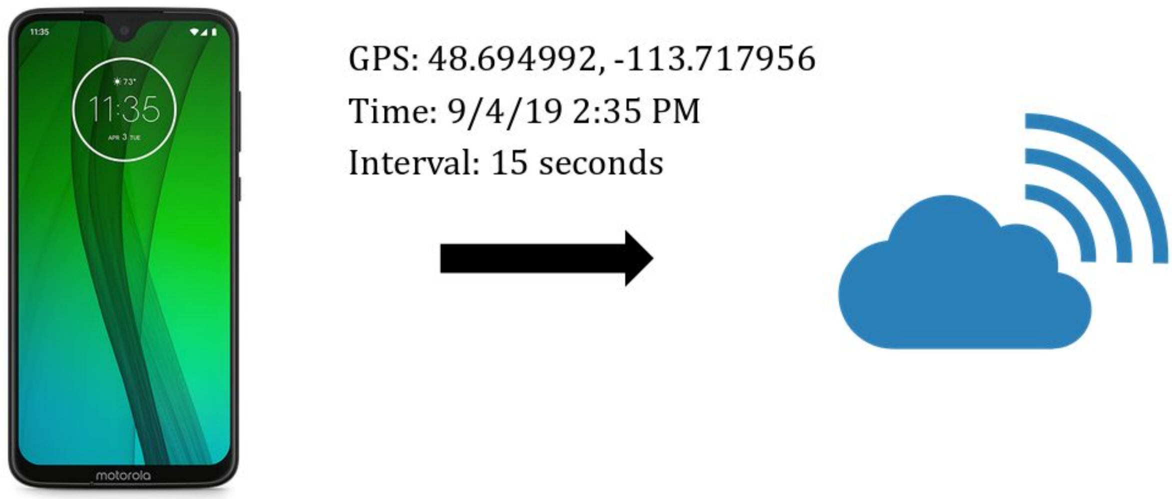


Figure 3: Graphic Overview of Application Functionality. Screenshot by Jason Jemison, 2019, containing images reprinted from *pixelprivacy.com* and *motorola.com*.

CHAPTER 2: BACKGROUND

The National Park System

The National Park Service (NPS) was created by Woodrow Wilson in 1916 as an agency within the Department of the Interior. This service was not created until over forty years after the establishment of the first National Park in Yellowstone. Previously, the nation's parks and historical locations had been managed by several different departments, including the departments of War, Agriculture, and the Interior. The purpose of the National Park Service is to preserve "unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations" (National Park Service, 2019). It was not until the creation of the National Park Service, that the parks were officially set aside for preservation (National Park Service, 2018).

Figure 4: National Park Service Logo. Reprinted from *Wikimedia.org*.

Stephen Mather, an industrialist millionaire, served as the first head of the National Park Service, after successfully lobbying for its creation. Mather expressed his disappointment with the parks' poor conditions through his lobbying in Washington, D.C.. Mather used his wealth to build awareness of the parks and to purchase new land, which he donated to the park service. Through a partnership with the automobile industry, Mather worked to expand access to the parks to common citizens (Library of Congress, 2009).

As of 2019, the National Park Service encompasses 419 protected sites, which cover more than 84 million acres in the United States. Out of the protected sites, 61 are National Parks. The NPS has received over 300 million visitors annually since 2015. The NPS has a structured employee system to keep it in operation. The NPS employs 28,000 employees year round, has more than two million annual volunteers, and a number of seasonal employees during times of high visitation. The largest portion of people employed by the NPS are the Park Rangers, who number more than 3,800. The Park Rangers are responsible for the safety of park visitors and ensuring they enjoy their time in the National Parks.

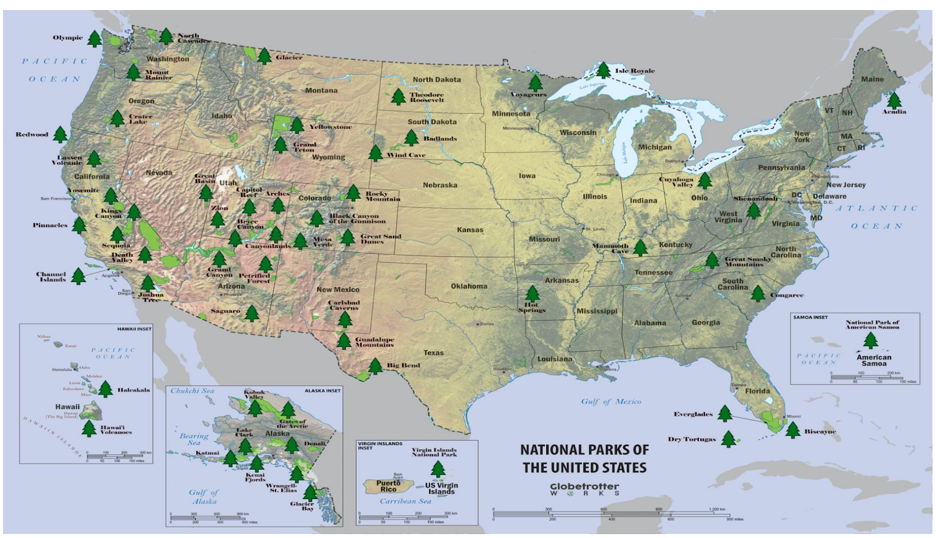


Figure 5: National Park Locations Across the United States. Reprinted from *Globetrotterworks.com*, by Globetrotter Works, 2019.

Glacier National Park

Glacier National Park (Glacier) is located in the Northwest corner of the state of Montana on the Canadian Border. Evidence of humans in the area dates back over 10,000 years. Before the park's establishment, there were many Native American tribes that occupied the area, including the Blackfeet, Salish, Pend d'Oreille, and Kootnei tribes. Eventually, the tribes signed treaties which would confine them to reservations. In the early 1800s, French, English, and Spanish trappers began exploring the area in search of beavers. In 1885, George Bird Grinnell started exploring the area. He quickly began pushing to turn the area into a national park. On May 11, 1910, President William Howard Taft signed the bill which established Glacier as the 10th national park (National Park Service, 2016).

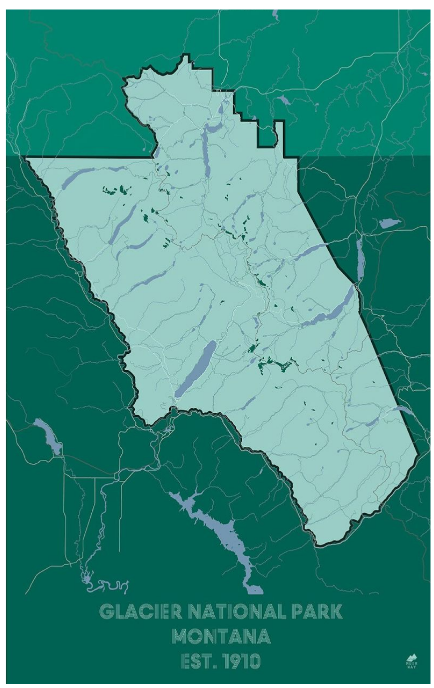


Figure 6: Map of Glacier National Park. Reprinted from *muir-way.com*.

Figure 7: Going-to-the-Sun Road. Reprinted from *nps.gov*.

In 1921, construction began on the park's famous Going-to-the-Sun Road. The road was considered complete in 1932, however, the road was not fully paved in asphalt until 1955. The road spans about 50 miles through the heart of the park and offers access to many of the park's main attractions. Also in 1932, Glacier became a part of the first International Peace Park with Waterton Lakes National Park (Waterton Lakes) of Canada. The idea of the Peace Park was not only to preserve biodiversity, but also to embody an idea of peace. However, the two parks functioned as one unit long before the charter, and the legislation was only used for official recognition of the relationship (National Park Service, 2016).

Figure 8: Waterton-Glacier Seal. By Mara Nunez, 2019.

Figure 9: Waterton-Glacier Peace Park. Park sign at the border crossing. Reprinted from *Wikipedia.org*, by Martin Kraft, 2013.

Today, Glacier is at one million acres in size and experiences about three million visitors annually. The main season for the park is from May until October, while the heaviest tourist activity occurs during the months of July and August. Visitors have the opportunity to experience 151 different trails that cover about 800 miles of the park. For visitors who stay for overnight, there are 13 different campgrounds to choose from along with various lodging. The park offers an extensive amount of activities during the summer months that range from horseback riding, to white water rafting, and different kinds of tours (National Park Service, 2017).

Glacier is also home to a wide range of different species of wildlife. There are about 70 different species of mammals, over 200 different species of birds, 24 species of fish, and about 2,000 different types of plants throughout the park. The majority of Glacier's ecosystem has remained unchanged since the early years of the park. Glacier contains 26 glaciers that are all slowly shrinking in size due to the rise in temperatures. The largest glacier, Harrison Glacier, is about one million square meters (National Park Service, 2017).

Traffic Congestion

Traffic congestion is a condition on roads that occurs when vehicles over-reach the carrying capacity of the road. Traffic congestion causes slower traveling speeds, longer travel times, and longer lines of vehicles (Definitions.net). There are many possible causes of traffic congestion, including events that negatively influence the traffic, a higher demand for road usage, and the physical features of the road. Traffic congestion can delay people's arrival times and cause major inconveniences. In modern society, people tend to have fast paced daily lives, and reliable travel times are essential (Federal Highway Administration, 2017).

Figure 10: Traffic Congestion in Glacier National Park. By Mara Nunez, 2019.

Mobile Application

A mobile application is a software program made to be downloaded onto a cellular device. Applications can come pre-installed or can be downloaded through digital distribution services. Mobile applications cover a variety of uses. These uses include tracking user’s health, entertainment purposes, scheduling and task management, and a variety of other services. Some applications require users to give the application permission to access specific phone capabilities. These capabilities include access to location services, contacts, camera, and storage (Federal Trade Commission, 2018).

Figure 11: Example Mobile Application. Reprinted from *affinitycuia.org.com,* by Affinity Credit Union, 2019

Global Positioning System

Global Positioning System (GPS) is a navigation system that broadcasts radio signals to people on or near the Earth. The signals are generated from satellites orbiting the Earth. The United State's Navstar GPS has 24 satellites that revolve around the Earth every 12 hours in six different orbital paths. The signals are received by a user's GPS unit. The unit calculates the time it takes the radio signals to travel from the orbiting satellites to the device and measures the distance to the satellite. This is done with four or more satellites. These measurements are then used to determine the latitude, longitude, and altitude of the device, which marks the user's location. A basic device can calculate the location with an accuracy of 33 feet. However, with newer technology and techniques, the location can be calculated with 0.4 inches of accuracy. GPS receivers are found in many civilian devices including automobiles, navigational units, and cell phones (Levy, 2010).

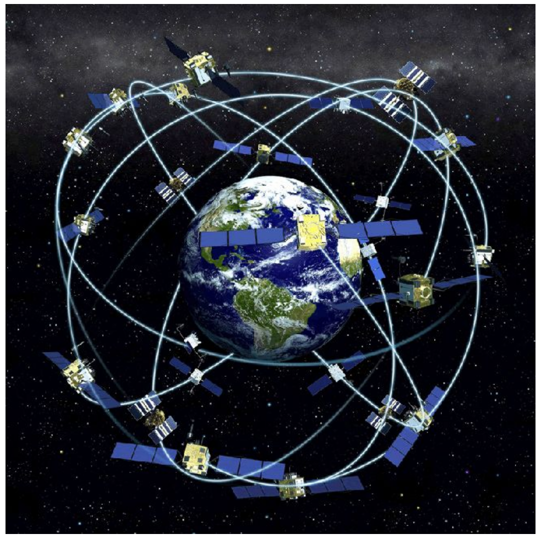


Figure 12: GPS Satellite Orbitals, path of GPS Satellites around the Earth. Reprinted from *National Oceanic and Atmospheric Administration*, 2007.

Existing Company Applications

Multiple companies have mobile phone applications on the Apple App Store and Google Play Store that are related to user experience in the National Parks. Some of these applications also have an in-app map that displays the user's location in real time. This GPS location collection is important for the purposes of this project.

Chimani

Chimani is a company that encourages users to experience the outdoors through their national park mobile applications. Their apps are available for both Android and Apple mobile devices. Chimani works closely with the National Park Service to ensure visitors have an enjoyable experience while visiting the parks (Chimani, 2019). Chimani's National Parks app has over 100,000 downloads on the Google Play Store. It was also their top grossing and most downloaded app of August 2019 (SensorTower, 2019).

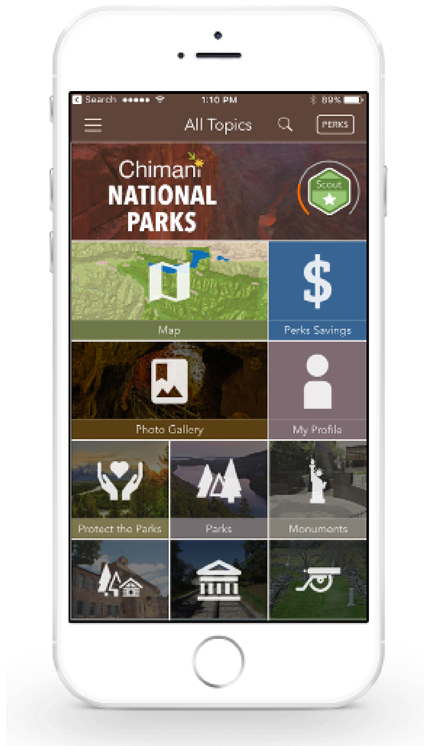


Figure 13: Chimani National Parks App. Reprinted from *Chimani.com,* by Chimani, 2019.

<u>OnCell</u>

OnCell is a United States-based company that manages tour-based mobile applications on both Android and iOS (Bloomberg, 2019). Many of their applications focus on tours for a variety of National Park sites. Since its founding in 2006, OnCell has formed a working relationship with the National Park Service and currently covers over 100 National Park sites with their applications (K. Pierce, personal communication, September 9, 2019). Their main app has over 10,000 downloads on Android (Google Play, 2019).

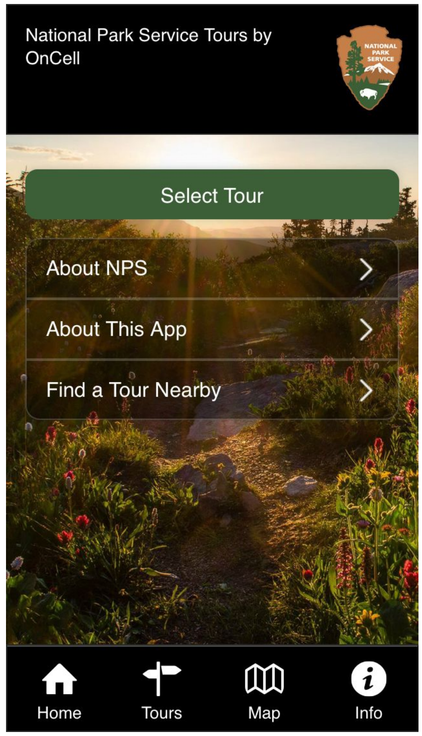


Figure 14: National Park Service Tours by OnCell, screenshot of application home page. By Kelly McCauley, 2019.

REI Co-op

Recreational Equipment, Inc. (REI) is an American outdoor equipment company founded in 1938. REI Co-op made a name for itself as a consumers' co-operative, meaning that it is owned and managed by consumers rather than shareholders (REI, 2019). In 2015, REI Co-op launched the REI Co-op Guide to National Parks app. The app relies on crowdsourcing to provide data on the national parks, such as where water sources and bathrooms can be found on various trails (Smith, 2016). The app currently has over 100,000 downloads on Android (Google Play, 2019).

Figure 15: REI Co-op Guide to National Parks. Reprinted from *Hikingproject.com*, by REI, 2019.

Request for Information

The NPS, along with several other government agencies, released a Request for Information (RFI) in the summer of 2018. The RFI focused on big data analysis in relation to GPS data. The NPS expressed an interest in learning how big data could be used to determine patterns of visitor use within the parks (National Park Service, 2018).

RFI for Mobile Device Big Data
Solicitation Number: 140P2018P0018
Agency: Department of the Interior
Office: National Park Service
Location: NPS - All Offices

Notice Type: Sources Sought	**Posted Date:** July 25, 2018
Response Date: Aug 27, 2018 2:00 pm Mountain	**Archiving Policy:** Manual Archive

Figure 16: Request for Information, screenshot of RFI information. By Julia Rivelli, 2019.

Request for Proposals

The National Park Service released a Request for Proposals (RFP) in the summer of 2019. They were seeking proposals from the public about data collection along with a transportation analysis. The RFP has many deliverables, some of which include Data collection and analysis plan, all data source files, and an existing visitor travel report. The RFP is especially interested in the route those are taking to travel from park to park. Along with this they would like a congestion analysis submitted with the proposal (National Park Service, 2019).

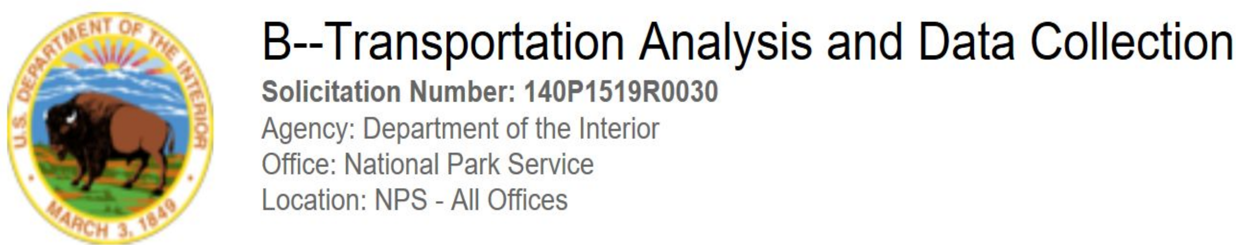


Figure 17: Request for Proposals, screenshot of RFP information. By Julia Rivelli, 2019.

Previous IQP Work

WPI has been working with the idea of a mobile tracking application for a couple years. The idea for the application started in Acadia National Park in 2018. The Acadia group developed a mobile application that could track visitor movements throughout the park in order to understand congestion and traffic patterns. The idea of this application was taken to Glacier in the fall of 2018. Big data and knowledge of visitor movements stayed with the parks interest as these projects were continued in both locations for the summer of 2019, in Acadia, and fall of 2019, in Glacier (WPI IQP Database, 2019).

CHAPTER 3: METHODS

The purpose of the project was to develop a mobile application to track visitor mobility and behavior. The project was completed in three main stages. A mobile application was developed to track visitor movements in Glacier. The collected GPS data was then visualized to show the application's functionality. Finally, big data projections were made to show how future correlations can be found in the data.

Developing the Mobile Application

Initial development began in April 2019 by James Plante and Jack Hogan for use in Acadia National Park. They completed development for use in Acadia in early July. The application collects the user's GPS location as they move through the park. This is done in the background to make the app as unobtrusive as possible. The location is collected every 15 seconds and timestamped accordingly. Once the phone establishes an internet connection, the location and timestamp data is uploaded to a server hosted by WPI. After the data is uploaded to the server, it is deleted from the phone. The collected GPS is not associated with any specific device information, making all the data anonymous.

The data is time stamped every 15 seconds to provide an accurate account of visitor movement through the park. By timestamping the data, knowledge about how the visitor is moving can be inferred. It can be distinguished if the user is hiking or walking, biking, or driving in the park. It can also be seen if the user stopped for an extended time at a certain place. This detailed GPS information gives a thorough understanding of visior mobility and behavior in the park.

The same application platform had to be updated for use in Glacier National Park in late August. The required changes were to update the geofencing and the graphics within the application. Android Studio was used to perform these updates. The first change was to update the geofencing to enable the application to work in Glacier. A circular geofence was used for the purposes of the application. The center of the geofence was set to Logan Pass Visitor Center along Going-to-the-Sun road, as this was approximately the center of Glacier National Park.

Figure 18: Circular Geofence Map, screenshot on Google Earth. By Jason Jemison, 2019.

The coordinates of Logan Pass Visitor Center were found to be 48.694997, -113.717137. A radius of 95 kilometers was chosen for the geofence. A large radius was chosen to help show movement around the park as well. This suggestion was taken from Tara Carolin, who expressed that Glacier administration is curious about how people move around the park and navigate between entrances. Tracking movement through corridors around Glacier was also supported in the Request for Proposals, released by the NPS in July. After the geofencing was updated, the graphics and text of the application were updated to display graphics for Glacier and to update any Acadia information to say Glacier instead. In order to get the application functional for Glacier National Park, minimal changes had to be made because the same overall functionality was needed.

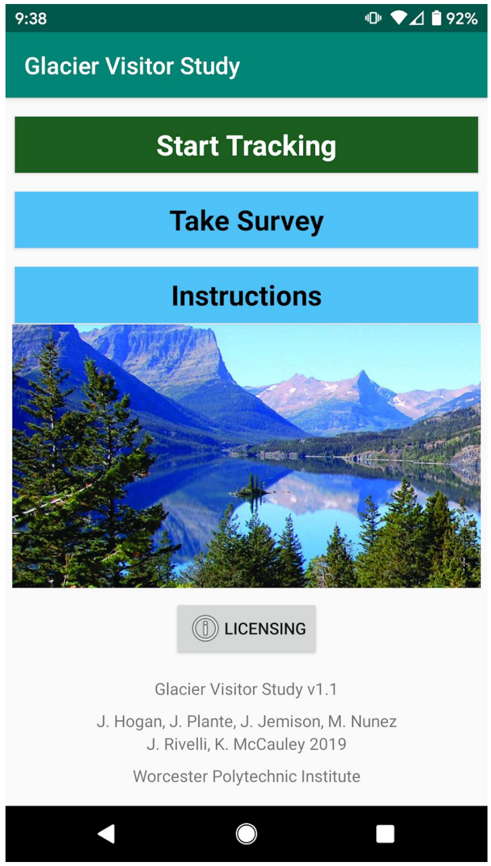


Figure 19: Screenshot of Glacier Mobile Application. By Mara Nunez, 2019.

Data Storage

In order to view the collected GPS data from users' phones, the data must be removed from the phone and stored in one location. For this project, a remote server was set-up through WPI for storing the GPS data. The application is designed to upload data points when the phone has an internet connection. A GPS datapoint and timestamp is collected every 15 seconds and stored on the phone until an internet connection is acquired.

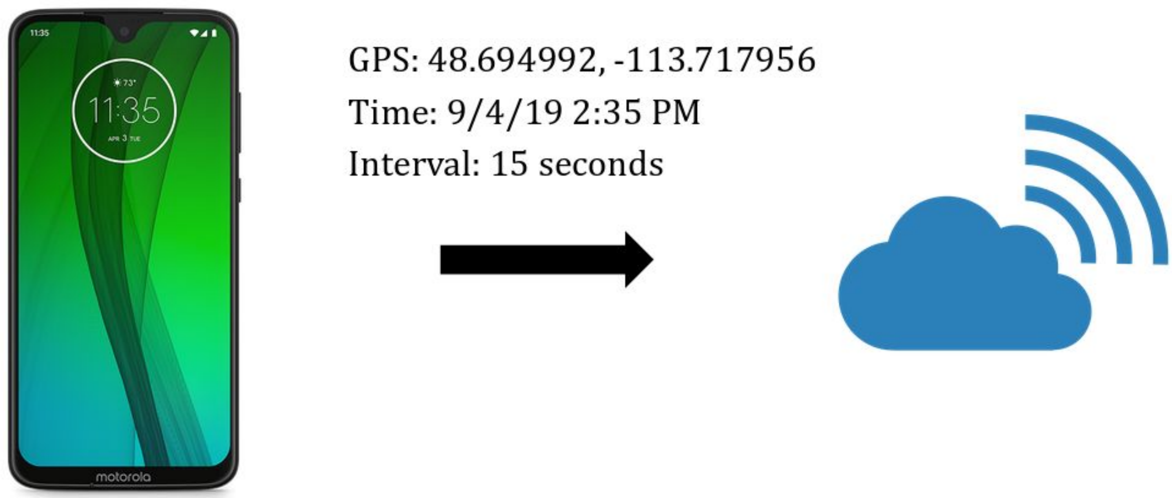


Figure 20: GPS Collection Flowchart. Screenshot by Jason Jemison, 2019, containing images reprinted from *pixelprivacy.com* and *motorola.com*.

When the phone has an internet connection, the data points are uploaded to the server. At this point, the GPS points are also erased from the phone, to keep the app as unobtrusive as possible. From here, the server can be accessed to download the collected data for eventual analysis and visualization.

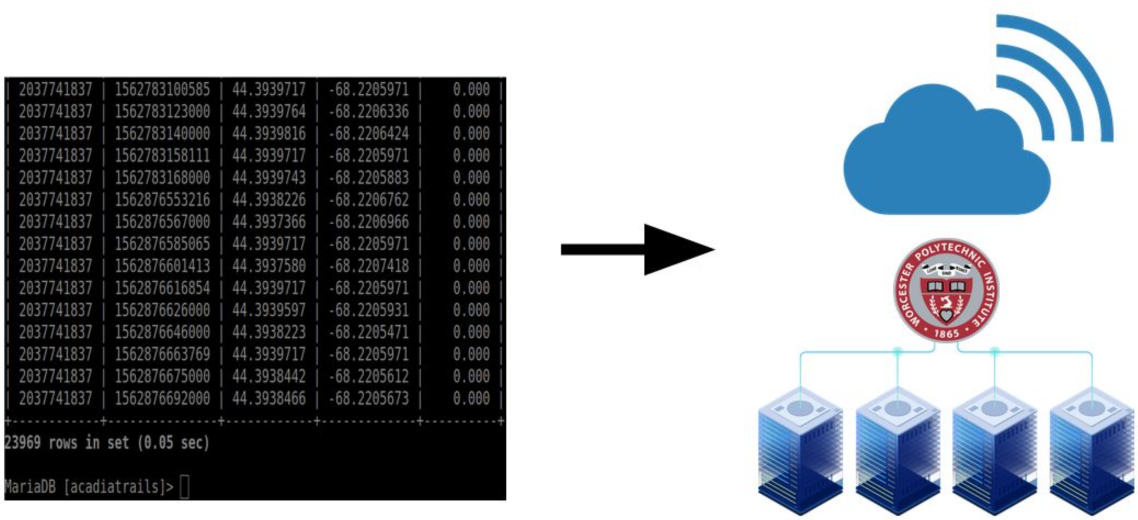


Figure 21: WPI Server Set-up. Screenshot by Frederick Bianchi, containing images reprinted from *pixelprivacy.com*, *wpi.edu*, and *microsoft.com*.

Testing the Mobile Application

To prove the functionality of the tracking application, it was tested in Glacier National Park. Ten WPI students tested the application over five weeks. They used the application for various activities throughout the park, including, driving along Going-to-the-Sun rRoad, hiking, and biking. At least one student in each project group had the mobile application, giving a wide variety of collected outing data, mimicking park visitors.

Throughout the testing period, the collected GPS data was viewed in order to verify the application was functioning properly. The collected GPS tracks were viewed by device, and it was confirmed entire tracks were being uploaded, despite devices not having an internet connection for the entirety of outings. The application was also tested to determine proper geofencing by driving to the boundary of the geofence to ensure the tracking stopped automatically. The range of the geofence was tested in three directions, southwest, northwest, and northeast, and was proven to be functioning.

Big Data Analysis

Big data analysis is the process of examining and manipulating data to show trends and correlations between data sets. By using large data sets, trends that are not necessarily intuitive can be found. Big data analysis can show these unintuitive trends, which allows for a more thorough understanding of the collected data. Data analysis can also be used to find correlations between data sets, including data sets from different periods of time (Galetto, 2016).

A predictive analysis can be performed on big data sets to find trends that are not necessarily intuitive. When millions of data sets are collected over the course of several years, many possible correlations can be found between these data sets. A predictive analysis can be performed with given filters to help sort the data. An example would be using filters such as day of the year, weather, and time of day. These filters can be used to perform a more accurate analysis on the data. In the case of this project, a predictive analysis to find congestion patterns within the park could be run. A predictive analysis using big data can be taken a step further using less intuitive filters, such as gas prices and pollen count. With more filtering, more trends can be found. These trends could include ones as far-fetched as producing probabilities of rescues, accidents, and deaths in certain locations. All of these trends would be invisible without the use of big data and predictive analyses.

Visualizing Collected GPS Data

Data visualization is very important for big data analysis. Large data sets can be hard to understand, and showing the data through an image can often be more helpful than just words and numbers. When the GPS data was collected from the phone application, it was uploaded to and stored on the WPI server. It could then be accessed and downloaded as a text file. The text file was downloaded and copied into an Excel workbook for more usability. A column was added into the Excel worksheet that converted the Unix time in milliseconds into an easily read format as seen in the Time column of Figure 22.

User ID	Unix Time	Time	Latitude	Longitude	Velocity
1681812179	1567613188206	9/4/19 10:06 AM	48.3983595	-114.040816	0

Figure 22: Excel Sheet, screenshot of Excel Sheet displaying data. By Mara Nunez, 2019.

This data was then filtered into chronological order, and uploaded into ArcGIS Online. ArcGIS Online is a data visualization tool that allows for quick map making with the use of a spreadsheet. ArcGIS Online was chosen due to its data visualization abilities and was accessible through WPI's software database. Using ArcGIS Online, the data points could be displayed in many ways. The project focused on displaying individual data points and heatmaps. The goal was to create an easy to understand visual of the student collected data.

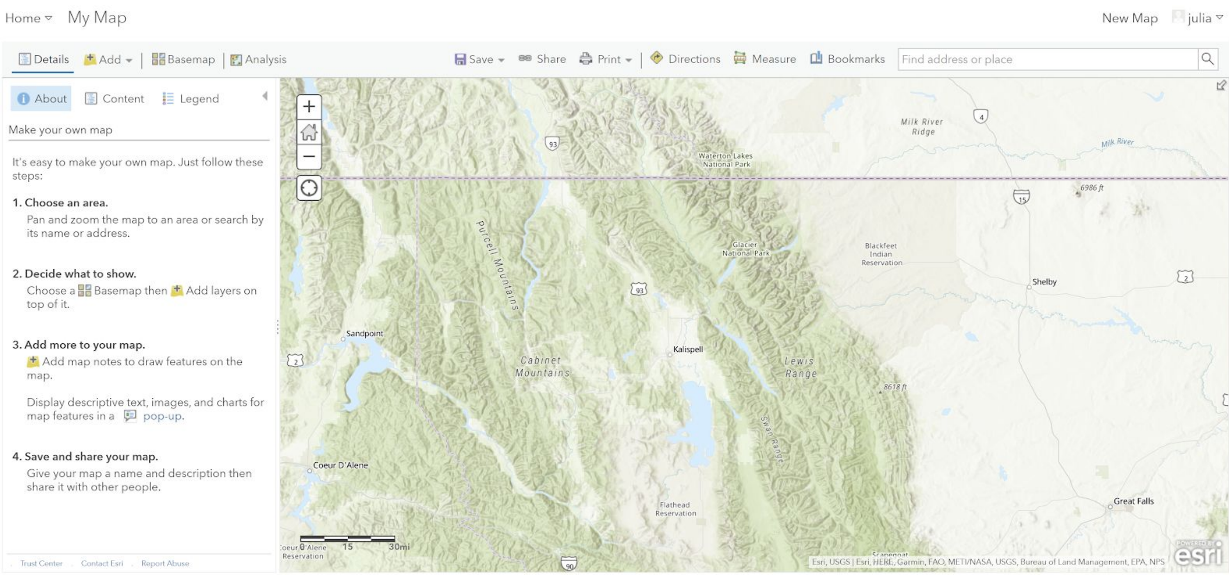


Figure 23: ArcGIS Online. Screenshot by Mara Nunez, 2019.

Communication with Potential Collaborators

It was determined that a collaboration with a company that developed an existing National Park app would be needed in the future. Three companies were contacted about the possibility of a collaboration with the NPS. These three companies host guide applications for National Parks. Each app uses real-time GPS data to show the user their location on a map to assist with hiking.

<u>Chimani</u>

Chimani was contacted after being recommended by the 2019 WPI Acadia research team as a possible company. Information was shared with Chimani about the mobile application functionality and what a collaboration with the National Park Service would entail. Kerry Gallivan, CEO and founder of Chimani, responded with interest. Gallivan replied that Chimani would need to develop a backend for the application to store GPS data to an external server. Chimani also mentioned that it is cautious about moving into GPS data storage due to privacy and user experience concerns. Gallivan noted that Chimani relies on a paid subscription model, though the majority of users do not have a subscription.

<u>Oncell</u>

Oncell was contacted about a possible collaboration with Glacier regarding the mobile application. Information about the project's mobile application and the goals of the project were shared. Kyle Pierce, senior territory manager of OnCell, expressed interest in further discussion. OnCell's tour applications incorporate geo-fenced alerts and trivia points, and the activation of those points is recorded. OnCell does not currently store GPS data beyond that. Pierce noted that though there were privacy concerns, OnCell had determined that storing GPS data externally would be useful in the long-term future. While the function was still waiting approval, it was already on OnCell's development schedule. OnCell believed that a collaboration would be possible due to their existing partnership with the NPS (K. Pierce, personal communication, September 9, 2019).

<u>REI Co-op</u>

REI Co-op was emailed, describing the function and purpose of the application and the idea of a partnership was described. An automated response was received, noting that the email had been seen and would be replied to within three to five business days. Since communication with REI Co-op began near the end of the project, no further communication occurred.

CHAPTER 4: RESULTS AND ANALYSIS

Visualizing Student Data

With the 10 students testing the application, over 30,000 GPS data points were collected around the park. The first step to visualizing student data was to create a track of one user's data through the park as seen in Figure 24. The track that was selected was one of a student who drove along the entirety of Going-to-the-Sun Road taking stops along the way. The time stamped GPS coordinates allow the users speed to be shown. From this, it can be determined if they are walking, biking, or driving. The track starts at the residences and then proceeds through the park. The track includes the hike of John's Lake Loop, which is zoomed-in on Figure 25. The track continues with pauses at assorted pull-offs as well as slow downs at congested traffic areas. There is also a large concentration of points near the Saint Mary visitor center as the student spent time looking around the center, and most likely ate lunch nearby. These data points can be seen in Figure 26. The track also follows the student driving back down the road and returning to the residence. A more detailed description of a different single visitor track can be found in Appendix A.

Figure 24: Single User Data, ArcGIS Online map created by Mara Nunez, 2019.

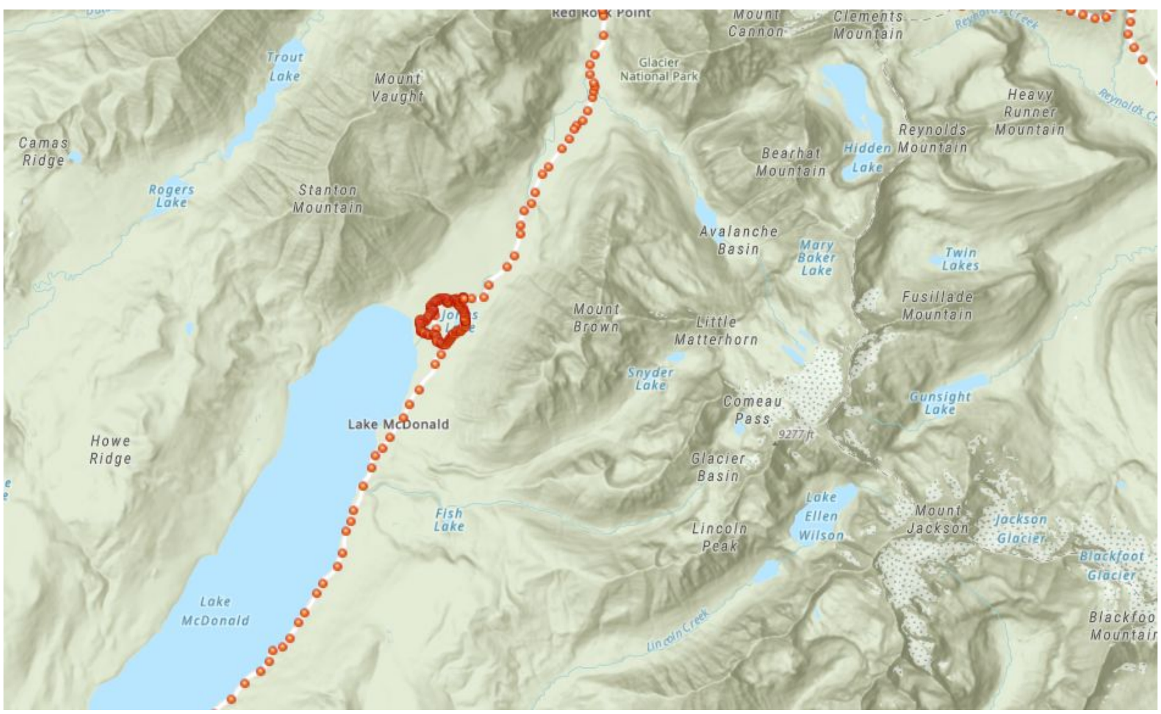


Figure 25: Single User Data John's Lake Loop Zoom, ArcGIS Online map created by Mara Nunez, 2019.

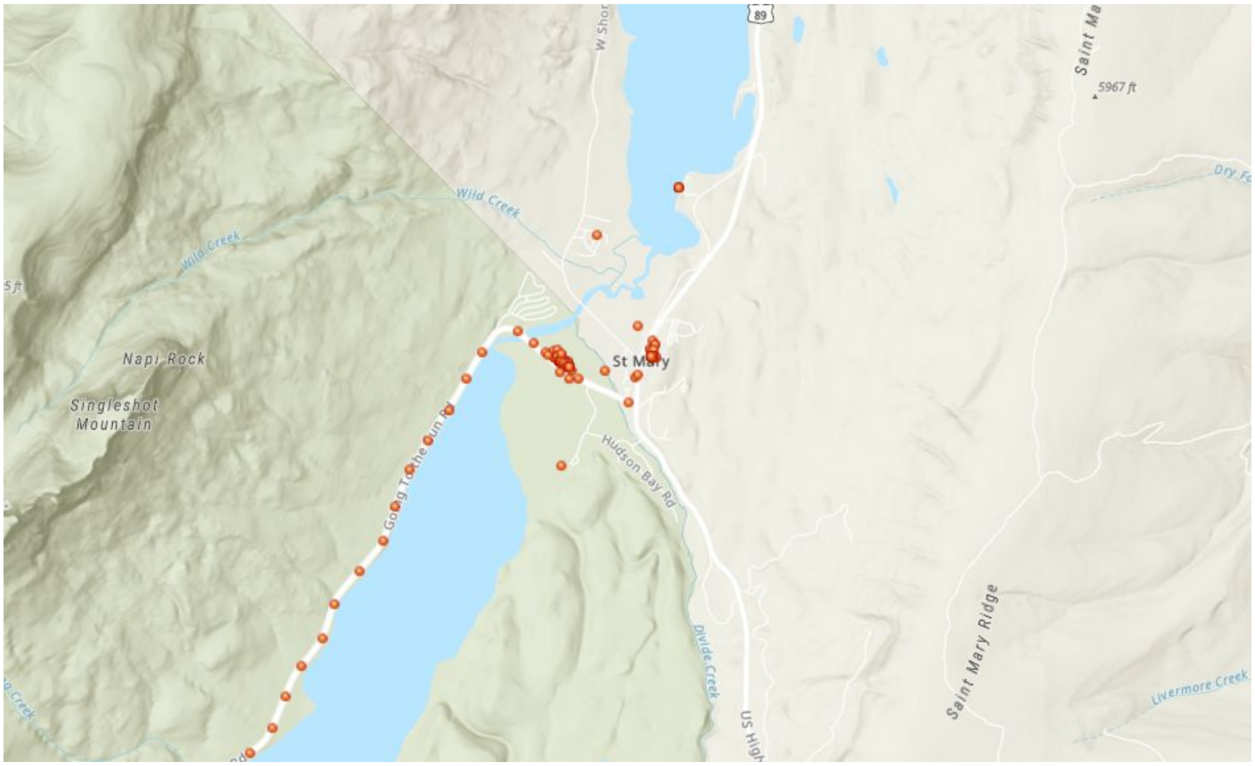


Figure 26: Single User Data Saint Mary Zoom, ArcGIS Online map created by Mara Nunez, 2019.

The next step was to visualize all of the student collected data at once. Figure 27 shows all of the data points on one map. This shows where visitors went in general, but does not give any information on how many visitors went to a place.

Figure 27: All Data Points, ArcGIS Online map created by Mara Nunez, 2019.

The next map created was a heat map. A heat map shows the varying concentrations of data points. Figure 28 shows the heat map created with the collected data. The two largest concentrations can be seen in the two locations where students were living. The other notable locations include the visitor centers at Logan Pass and Saint Mary and popular hiking trails.

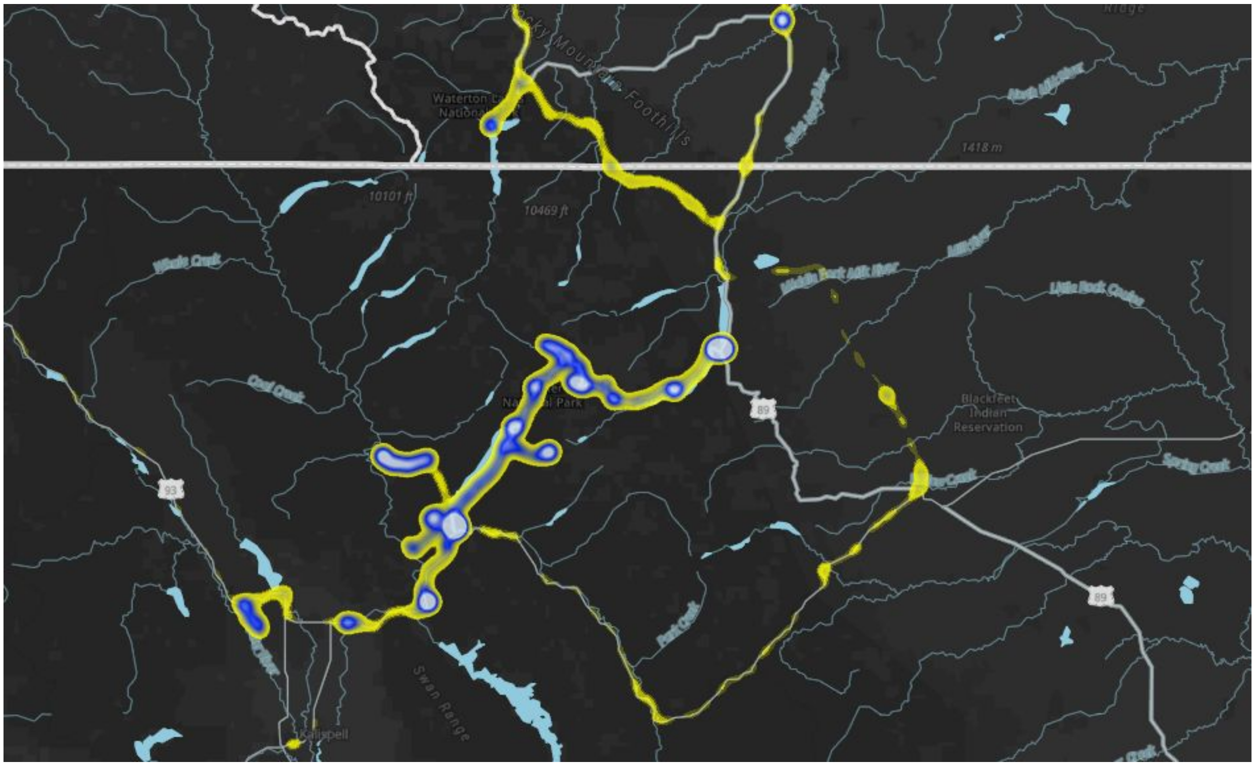


Figure 28: Collected Data Heat Map, ArcGIS Online map created by Mara Nunez, 2019.

These data visualizations provide examples of what can potentially be visualized for the park staff viewing the data. The single user track shows a direct example of a visitor's behavior. The heat map shows what could be used on a day to day basis to predict where the higher points of congestion will be. These visualizations combined with big data analysis can create useful information for park management. These visualizations are just the beginning of what can be done with collected tracking data. The possibilities for data visualization are endless.

Projected Big Data Visualization

Once location data is being tracked over many years, a large amount of data will be accumulated. Data collected over 5 years could be over 10's of millions of data sets. This data can then be visualized and analyzed to show correlations and patterns that are not necessarily intuitive. Since the project is unable to collect the amount of data that would be needed to properly visualize the data, data projections were created. Figure 29 is an example of a possible scenario after years off app use and collecting 20 million of data sets.

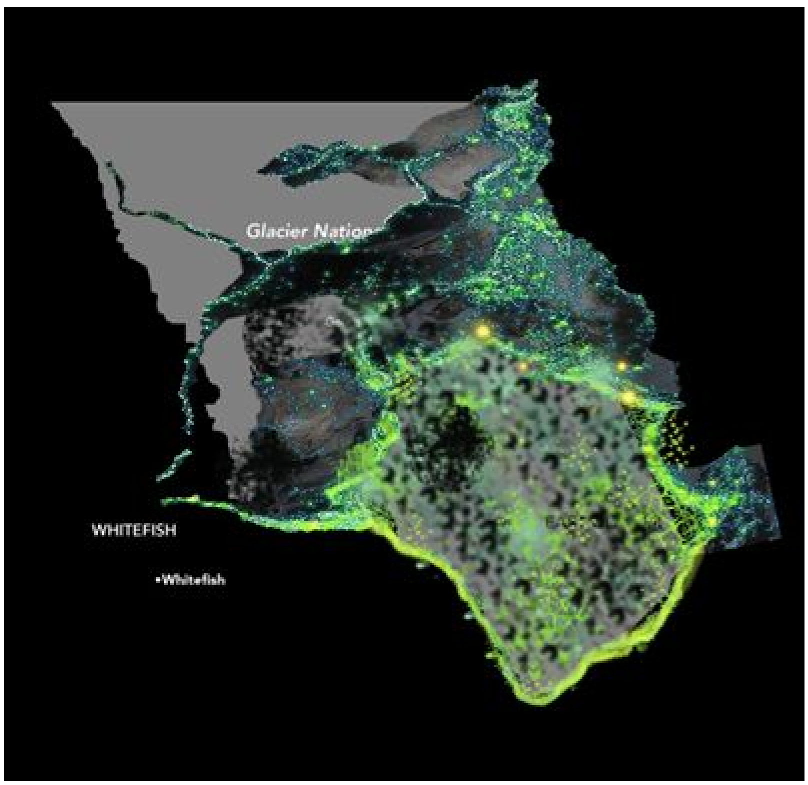


Figure 29: Big Data Projection, screenshot by Mara Nunez, containing images reprinted from *smithsonianmag.com*, by John Nelson, and *glacierparkcollection.com*.

Once this data is visualized, trends will start to be seen. For example, the more notable areas of Figure 29 are along the roads within and around the park. These are the most easily accessible areas, therefore they would have the most data points. When filters are applied to find correlations between data sets, portions of the data become areas of interest. These areas of interest can then be highlighted on the visualization in a variety of ways. Filters such as day of the year, time of day, temperature, and weather can all be applied to find different correlations. For example, Figure 30 shows the map with the filters of July 5th, 1:00 pm - 4:00 pm, 85°, and sunny weather. A predictive analysis could be run on the map to show congestion. The red spots on Figure 30 show where the highest congestion will be with the applied filters with a probability of 85%.

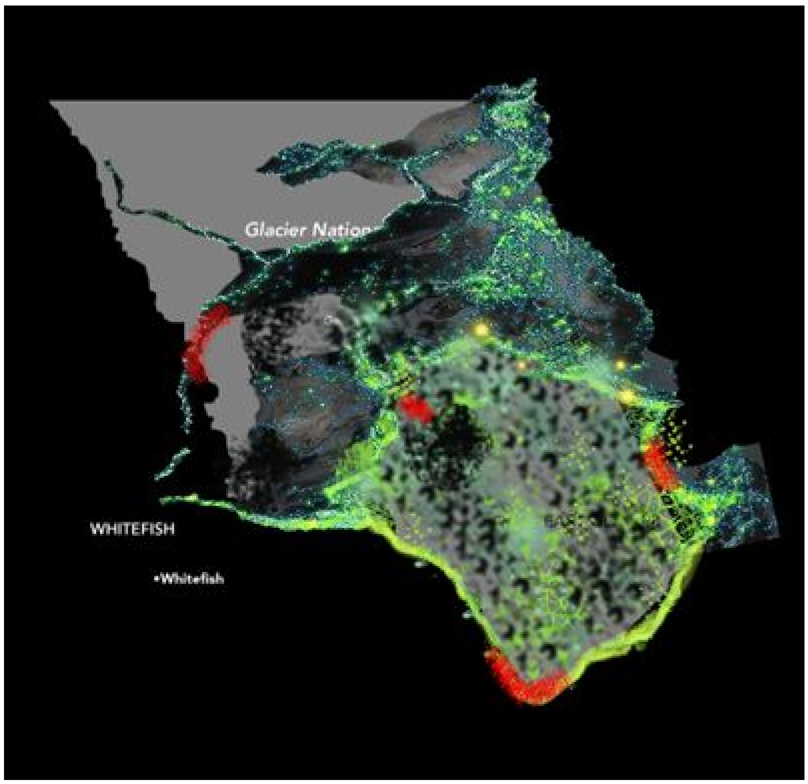


Figure 30: Big Data Projection Predictive Analysis 1, screenshot by Mara Nunez, containing images reprinted from *smithsonianmag.com*, by John Nelson, and *glacierparkcollection.com*.

With the filters, a small change could be made such as changing the temperature from 85° to 75°, and this could cause changes to the predictive analysis. Figure 31 shows the same map with the filters the same except with the temperature as 75°, new correlations can be found. The red spots show where the congestion has moved to, but the probability has also changed to 79%.

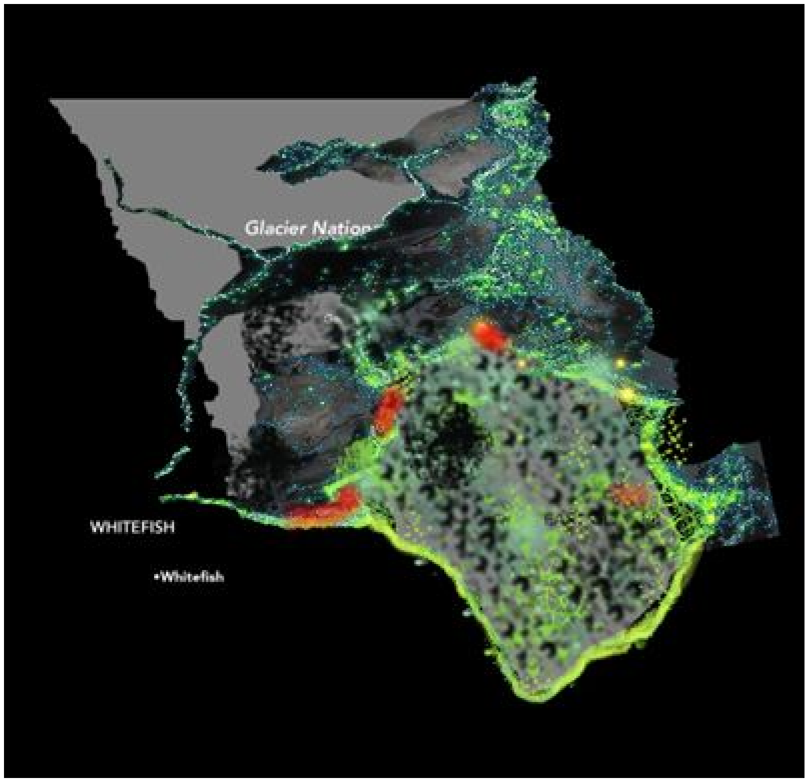


Figure 31: Big Data Projection Predictive Analysis 2, screenshot by Mara Nunez, containing images reprinted from *smithsonianmag.com*, by John Nelson, and *glacierparkcollection.com*.

Big data analysis can go above and beyond these few filters. Any database of information can be pulled in and used to find correlations and patterns. Databases such as gas prices or pollen count could be added to show correlations that people could not even begin to imagine. Figure 32 is an example of a map where the filters of July 5th, 1:00 pm - 4:00 pm, 85°, and sunny weather were applied. This time the predictive analysis was looking for rescues, traffic accidents, and deaths. The red arrows point to areas where rescues are likely with a probability of 85%. The white arrows point to areas where traffic accidents are likely with a probability of 79%. Then the orange arrows point to areas where deaths are possible with a probability of .001%. This analysis could hypothetically be done on any condition using any parameters. This would be an extremely useful prediction tool for park management.

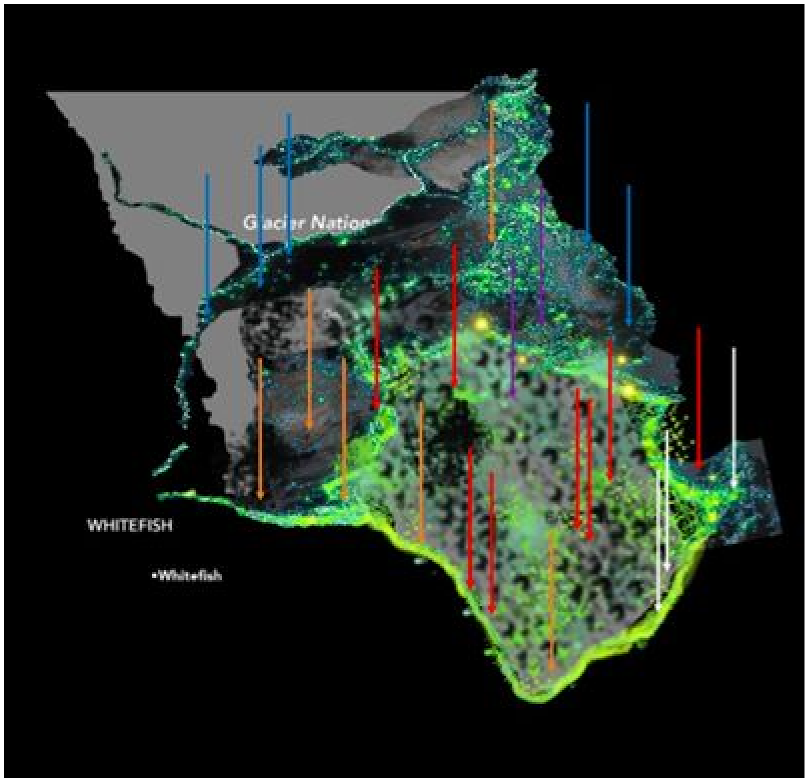


Figure 32: Big Data Projection Predictive Analysis 3, screenshot by Mara Nunez, containing images reprinted from *smithsonianmag.com*, by John Nelson, and *glacierparkcollection.com*.

These are just a few examples of hypothetical big data projections. These visualizations along with the collected GPS data could be used to create valid and useful information for park management. Using unique data visualizations allows for trends to be visually identified. There are many benefits of data visualization techniques. Data visualizations can allow for a more complete interpretation of collected data and more ease of identifying patterns and trends within the data (Patrao, 2019).

Application Relation to the Going-to-the-Sun Management Plan

The Going-to-the-Sun Management plan, released in September 2019, established an alternative plan that Glacier hopes to pursue to combat congestion within the park. Once Glacier implements its new management plan, it will need to determine the effectiveness of the changes. Currently, the park is largely limited to observation through the use of car counters or staff surveying on site. A visitor tracking application could be used to assist in observation. One of the park's main objectives is to understand visitor mobility and behavior. A mobile application is the most accurate way of collecting visitor movements as it does not rely on verbal accounts. The collected data can be used to determine the plan's success.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The main goal of this project was to develop a visitor tracking mobile phone application. The hope is that Glacier National Park will continue their focus on this project to obtain a much larger GPS location data set. For future work, a partnership with an existing company will be necessary.

Partnership with Existing Company

In order for the application to reach its full potential for aiding in learning about visitor trends in Glacier, a large user base is needed. The easiest way to achieve this is to partner with a company that already has an existing application related to the National Parks. Two aspects need to be addressed with a partnership; collecting user's GPS locations from the phone application, and establishing a storage plan for long term, large quantity, data storage. The two considerations taken into account when looking at companies for a possible collaboration were a national park application, and if the application had GPS functionality within the app.

Three companies were found to be good possibilities for a collaboration; OnCell, Chimani, and REI Co-op. All three of these companies have a mobile application guide to the national parks with a large existing user base. They all also have a trail map as part of their application, which shows the user's location in real time during their stay in the park. However, none of the companies are storing the user's GPS track from their visit for long term data analysis. With a collaboration, the chosen company would have to change the functionality of their application to store the GPS data. Furthermore, a collaboration with a company that specializes in big data analytics will be needed due to the large amounts of collected data. This company will have access to the proper software to analyze large data sets to find correlations between the collected GPS data and other data sets. This company would also have access to servers to store the large amounts of collected GPS data, solving the issue of data storage.

Conclusion

The project had three main components; the development of a mobile application, data collection, and data visualization. The application was developed to track visitors throughout Glacier National Park. It captures their GPS coordinates with a time stamp every 15 seconds. This allows for knowledge of where a visitor went, how they got there, and how long they stayed there. After development, the application was distributed to ten WPI students and their GPS coordinates were stored in a server hosted by WPI.

ArcGIS Online was used for data visualizations after sufficient data was collected from students. The visualizations made with ArcGIS Online showed hiking, biking, driving, and stops around Glacier. This method of data collection proved to be a feasible way to understand visitor mobility and behavior. If the app is used for many years and millions of data sets are acquired, many correlations can be found. The use of big data allows for predictive analyses to be performed. Correlations amongst many things can then be found through different filters and parameters.

In the end, a final recommendation was offered to the National Park Service. For further success in tracking visitor mobility a partnership with an existing company would be needed. Chimani, OnCell, and REI Co-op are all companies who have National Park applications that track visitors movements. However, none of these companies are storing this GPS data. A partnership will allow for a larger established user base and GPS location data storage.

REFERENCES

Barrameda C. E., Vose T. R., & Rizzo T. A. (2018). *Congestion Management in Glacier National Park*. (Undergraduate Interactive Qualifying Project No. E-project-101118-223807). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://digitalcommons.wpi.edu/iqp-all/5127/

Bloomberg. (2019). *OnCell Systems Inc.* https://www.bloomberg.com/profile/company/0030100D:US

Byron, E. (2019, September 10). *One-way trails? Parking permits? Glacier mulls changes to alleviate congestion.* Retrieved from https://missoulian.com/news/local/one-way-trails-parking-permits-glacier-mulls-changes-to-alleviate/article_d4d47eb5-b4db-50b6-a326-963d4b223578.html

Chimani. (2013, April 23). Chimani Celebrates National Park Week with the Release of Five New National Park Mobile Apps and New Innovative Features. Retrieved from https://blog.chimani.com/2013/04/23/chimani-celebrates-national-park-week-with/.

Clifford, N. J., Cope, M., Gillespie, T., & French, S. (Eds.). (2016). Key methods in geography. Los Angeles: SAGE.

Cohn, M. (2019). User Stories and User Story Examples by Mike Cohn. Retrieved April 14, 2019, from Mountain Goat Software website: https://www.mountaingoatsoftware.com/agile/user-stories

Committee for Oversight and Assessment of U.S. Department of Energy Project Management. (2005). Measuring performance and benchmarking project management at the department of energy. Washington, D.C.: National Academies Press. Retrieved from https://www.nap.edu/read/11344/chapter/5.

Definitions.net. "Definitions for Traffic Congestion." What Does Traffic Congestion Mean?, Retrieved from www.definitions.net/definition/traffic congestion

Devlin, V. (2013, November 19). Director of Glacier research center receives National Park Service award. Retrieved from https://missoulian.com/news/state-and-regional/director-of-glacier-research-center-receives-national-park-service-award/article_94a33b26-5176-11e3-83e0-001a4bcf887a.html

Elmuti, D., & Kathawala, Y. (1997). An overview of benchmarking process: A tool for continuous improvement and competitive advantage. Benchmarking for Quality Management & Technology,4(4), 229-243. doi:10.1108/14635779710195087

ESRI (2019). About ArcGis. Retrieved from https://www.esri.com/en-us/arcgis/about-arcgis/overview.

Federal Highway Administration. (2017, February 01). Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation. Retrieved from https://ops.fhwa.dot.gov/congestion_report/chapter2.htm

Federal Trade Commission. (2018, March 13). Understanding Mobile Apps. Retrieved from https://www.consumer.ftc.gov/articles/0018-understanding-mobile-apps

Galetto, M. (2016, January 20). What is data analysis? Retrieved from https://www.ngdata.com/what-is-data-analysis

Germann, D. (2013, November 8). Research Learning Center director receives regional award. Retrieved from https://www.nps.gov/glac/learn/news/research-learning-center-director-receives-regional-award.htm

Glacier National Park (2019). Going-to-the-Sun Road corridor management plan environmental assessment. Retrieved from https://parkplanning.nps.gov/document.cfm?documentID=98289

Google Play. (2019, August 18). REI National Park Guide & Maps. Retrieved from https://play.google.com/store/apps/details?id=com.toursphere.nps&hl=en_US.

Google Play. (2019, September 27). National Park Service Tours. Retrieved from https://play.google.com/store/apps/details?id=com.toursphere.nps&hl=en_US.

Hogan, J. & Plante. J. (2019). *Acadia Visitor Study: A Mobile Tracking Application*. Unpublished Interactive Qualifying Project. Worcester Polytechnic Institute.

IBM (2019). Features and modules. Retrieved from https://www.ibm.com/products/spss-statistics/details

Kendrick, T. (2013). The project management tool kit : 100 tips and techniques for getting the job done right. Retrieved from https://ebookcentral-proquest-com.ezproxy.wpi.edu

Lawrence, T., PhD. (2018, April 5). Brainstorming. Retrieved from https://www.projectmanagement.com/wikis/233029/Brainstorming

Levy, M. (2010). The britannica guide to inventions that changed the modern world: GPS. New York, NY: Rosen Educational Services

Library of Congress. (n.d.). Brief history of the national parks. Retrieved from https://www.loc.gov/collections/national-parks-maps/articles-and-essays/brief-history-of-the-national-parks/

McLeod, S. (2008). Saul McLeod. Retrieved from https://www.simplypsychology.org/likert-scale.html

Nadeau G. T., Charbonneau J. L., Caltabiano J. P., & Fischler M. A. (2018). *Visitor Cell Phone Application: An Innovative Design to Monitor Visitor Mobility in Acadia National Park*. (Undergraduate Interactive Qualifying Project No. E-project-080218-145202). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://digitalcommons.wpi.edu/iqp-all/5149

National Park Service. (2016, June 13). Early settlers. Retrieved from https://www.nps.gov/glac/learn/historyculture/early-settlers.htm

National Park Service. (2016, June 18). American Indian tribes. Retrieved from https://www.nps.gov/glac/learn/historyculture/tribes.htm

National Park Service. (2016, August 22). People. Retrieved from https://www.nps.gov/glac/learn/historyculture/people.htm

National Park Service. (2016, September 24). History & culture. Retrieved from https://www.nps.gov/glac/learn/historyculture/index.htm

National Park Service. (2017, June 13). Fact sheet. Retrieved from https://www.nps.gov/glac/learn/news/fact-sheet.htm

National Park Service. (2018, May 14). Quick history of the National Park Service. Retrieved from https://www.nps.gov/articles/quick-nps-history.htm

National Park Service. (2018, August 9). Going-to-the-Sun road general info. Retrieved from https://www.nps.gov/glac/planyourvisit/gtsrinfo.htm

National Park Service (2018). RFI for mobile device big data (140P2018P0018). Retrieved from https://www.fbo.gov/index.php?s=opportunity&mode=form&id=ccc89704f7d6963a2f91a6e63356894e&tab=core&_cview=0

National Park Service. (2019, April 14). What we do. Retrieved from https://www.nps.gov/aboutus/index.htm

National Park Service. (2019, April 14). National park system. Retrieved from https://www.nps.gov/aboutus/national-park-system.htm.

National Park Service (2019). B--Transportation Analysis and Data Collection. Retrieved from https://www.fedconnect.net

National Park Service. (2019). Recreation visitors by month - Glacier NP [Fact sheet]. Retrieved from https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20reports/Recreation%20Visitors%20By%20Month%20(1979%20-%20Last%20Calendar%20Year)

National Workshop on Large Landscape Conservation. (2014). Mary Riddle. Retrieved from https://nwllc.confex.com/nwllc/2014/webprogram/Person329.html

Patrao, L. (2019, May 22). Needs And Benefits Of Data Visualization. Retrieved from https://www.edureka.co/blog/needs-and-benefits-of-data-visualization/.

Rei. (2019). About REI: REI Co-op. Retrieved from https://www.rei.com/about-rei.

SensorTower. (2019, September). Chimani, Inc.Retrieved from https://sensortower.com/ios/publisher/chimani-inc/373153981.

Smith, T. R. (2016, March 17). REI and Hiking Project team up for a promising national parks app. *Washington Post*. Retrieved from https://washingtonpost.com/lifestyle/magazine/rei-and-hiking-project-team-up-for-a-promising-national-parks-app/2016/03/11/186eec74-d5a6-11e5-b195-2e29a4e13425_story.html

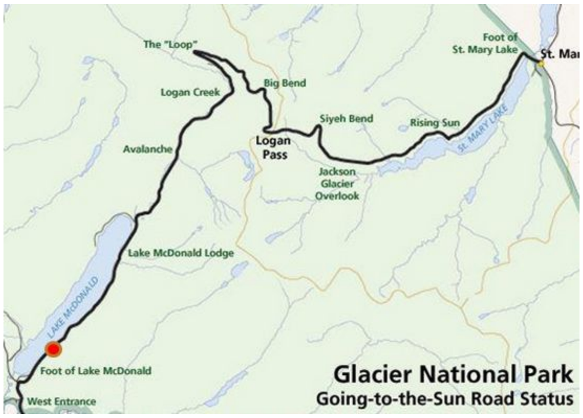
Stavros, J. & Hinrichs, G. (2009). The thin book of SOAR: Building strengths-based strategy. Bend, OR : Thinbook Publishing. Retrieved from https://libraryguides.missouri.edu/c.php?g=28374&p=4304702

Worcester Polytechnic Institute. (2019). Interactive Qualifying Projects: Worcester Polytechnic Institute. Retrieved from https://digitalcommons.wpi.edu/iqp-all/.

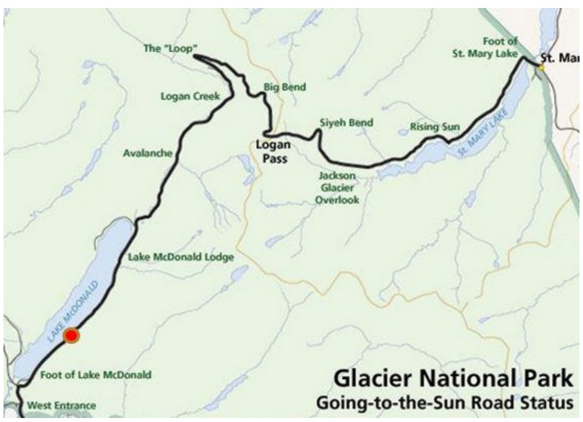
Writing Effective User Stories - Tech at GSA. (n.d.). Retrieved April 14, 2019, from Tech at GSA.gov website: https://tech.gsa.gov/guides/effective_user_stories/

APPENDIX A: SINGLE USER GPS TRACK

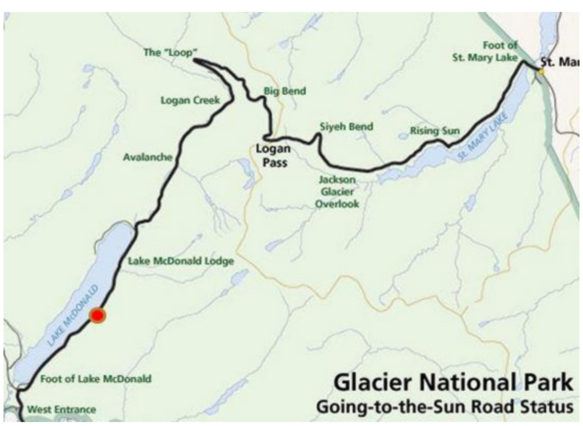
The following images show an example of a single user's GPS track through Glacier.



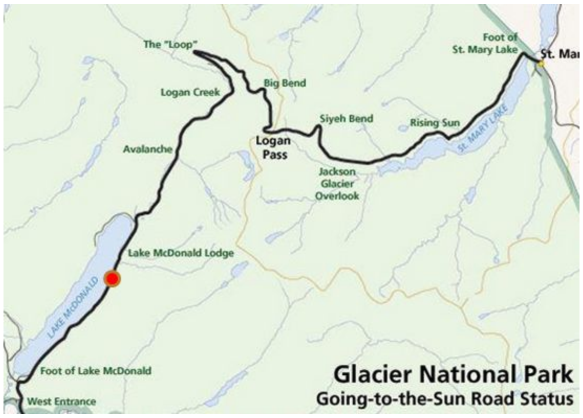
The visitor enters the park at the West Glacier entrance.



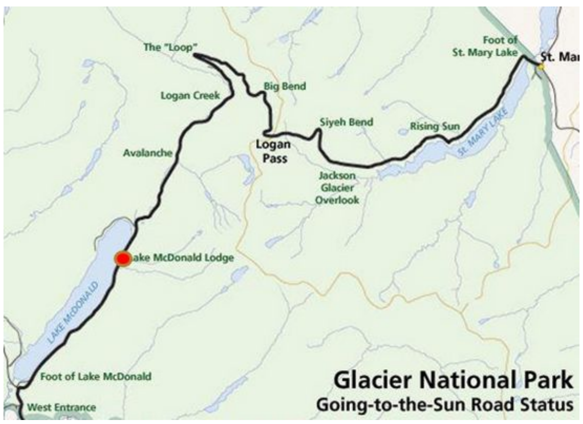
The visitor drives on Going-to-the-Sun Road along Lake McDonald.



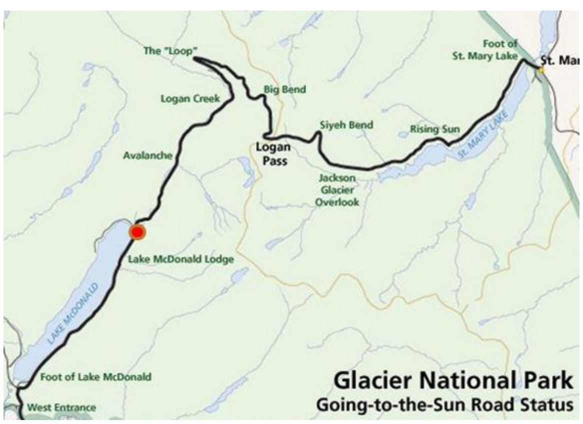
The visitor continues driving along Lake McDonald. We can tell they are driving based on the time stamped GPS coordinates.



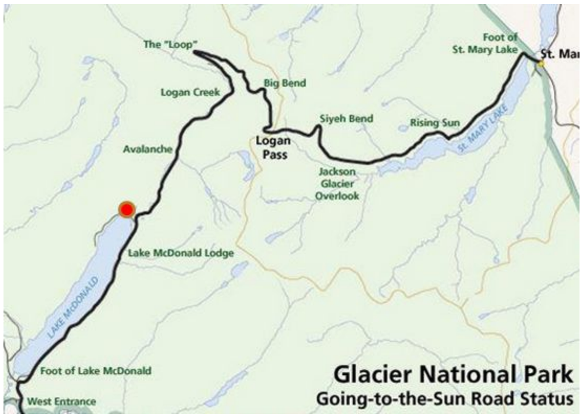
The visitor continues driving along Lake McDonald.



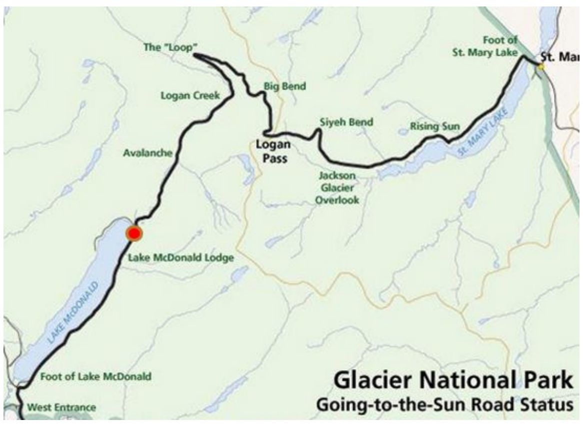
The visitor continues driving along Lake McDonald.



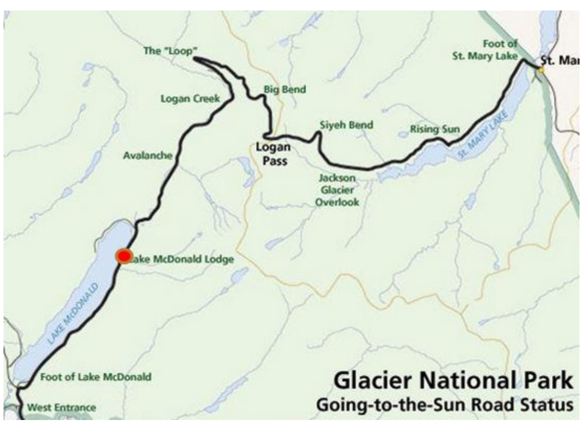
The visitor turns down a road at the end of Lake McDonald.



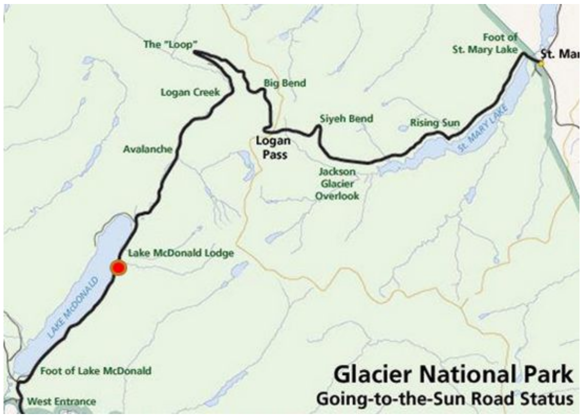
The visitor realizes that the road they turned down is closed.



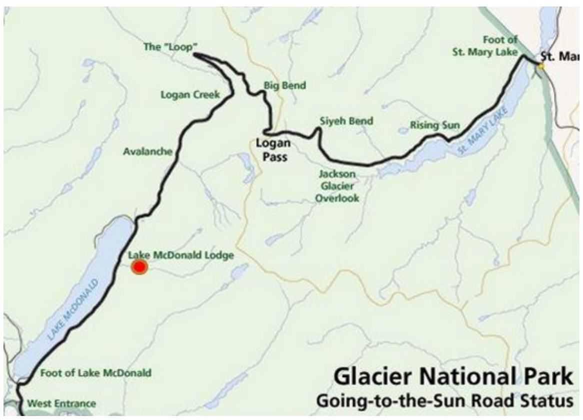
The visitor then turned around and went back on Going-to-the-Sun Road.



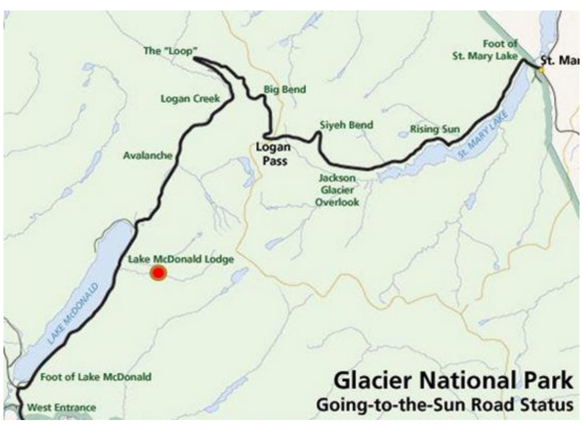
The visitor then back tracked down the road.



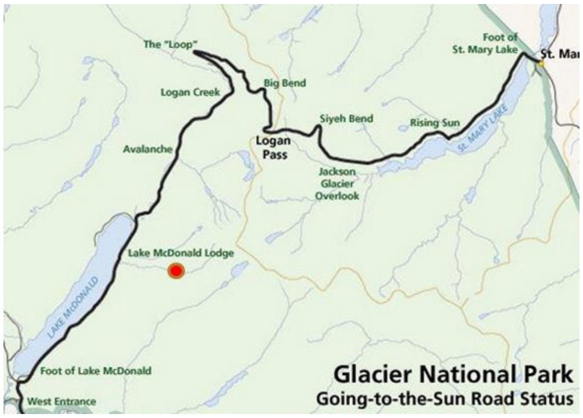
The visitor continues to back track.



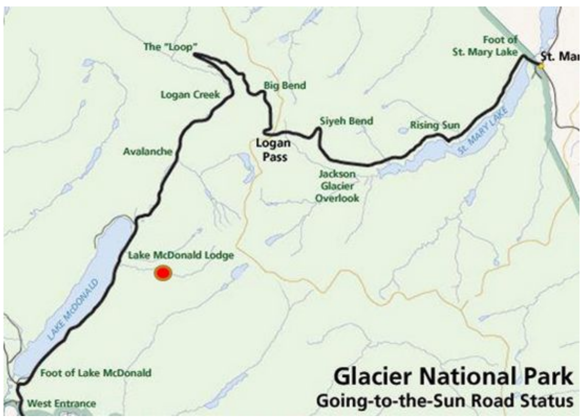
The visitor decides to go on a hike off of Lake McDonald.



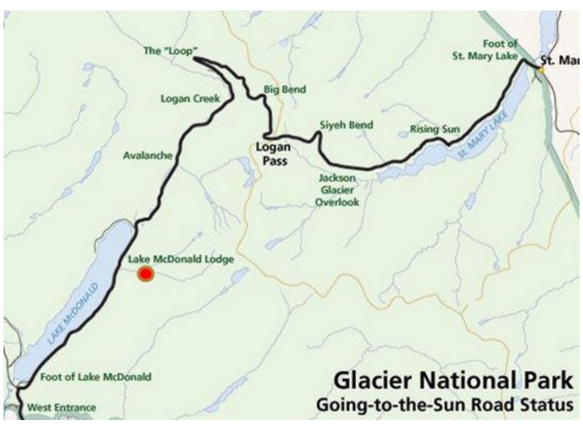
The visitor continues the hike.



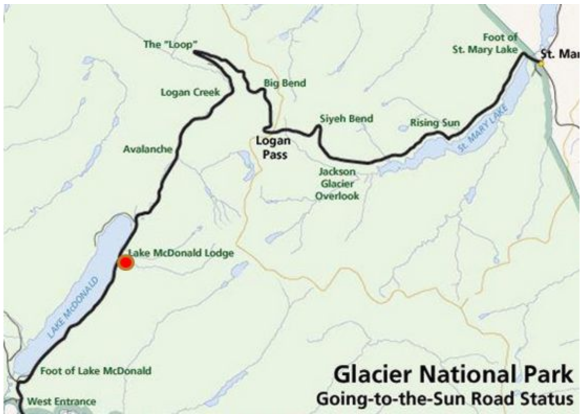
The visitor continues the hike.



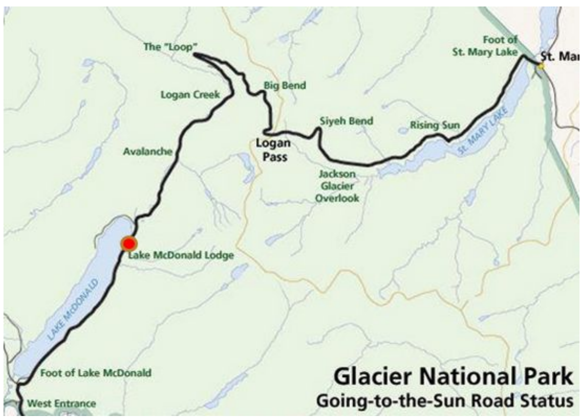
The visitor continues the hike.



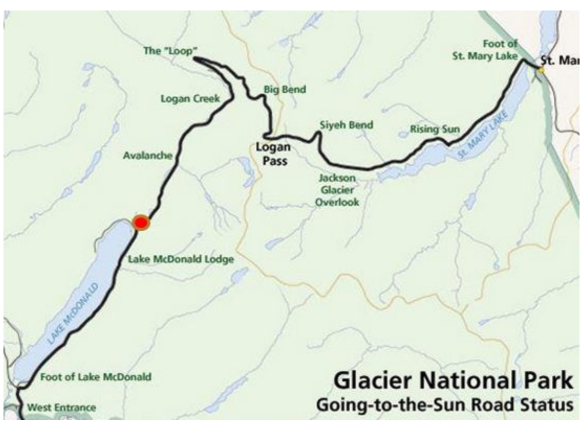
The visitor then stops for about an hour at the end of the hike. During this time it is possible they took a break, ate lunch, or enjoyed a scenic view.



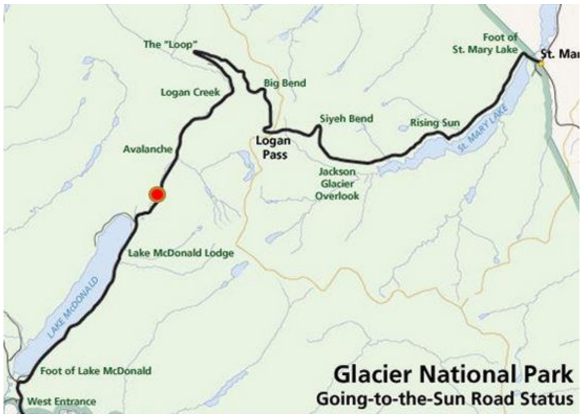
The visitor then gets back on the road.



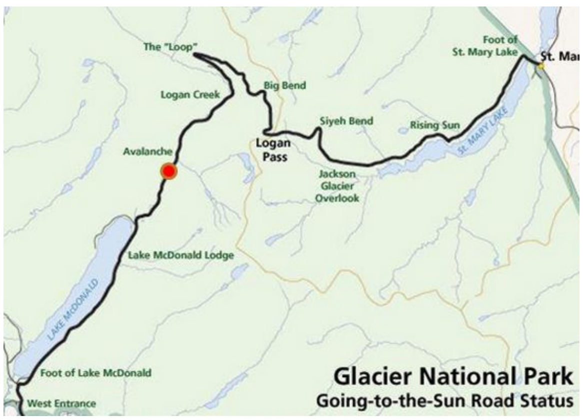
The visitor continues up the road towards the Avalanche parking area.



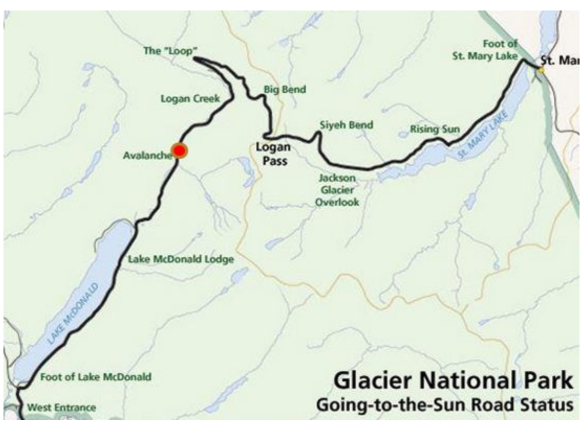
The visitor continues up the road towards the Avalanche parking area.



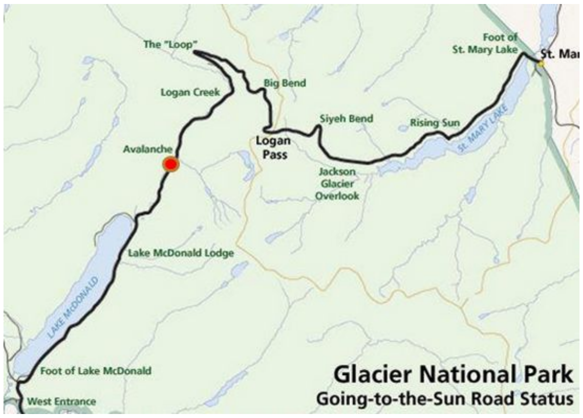
The visitor continues up the road towards the Avalanche parking area.



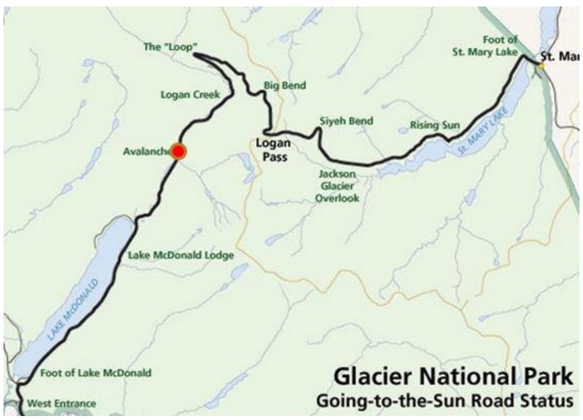
The visitor arrives at the Avalanche parking area.



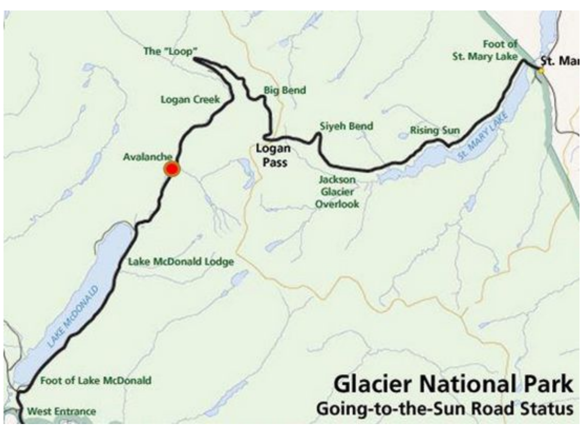
The visitor looks for a parking space at Avalanche.



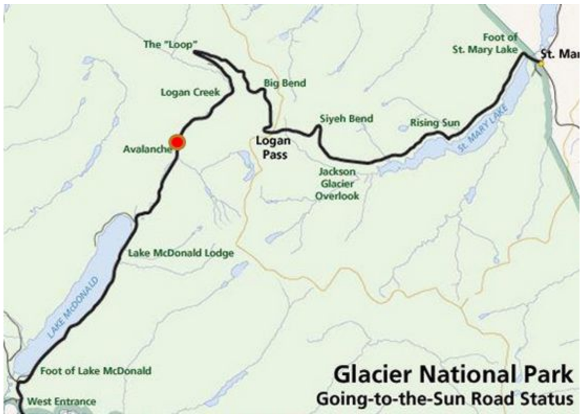
The visitor cannot find a parking spot and loops around the parking area in search of somewhere to park.



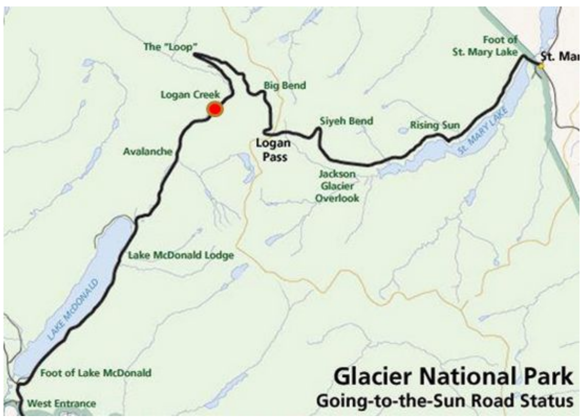
The visitor continues to loop around looking for a parking spot.



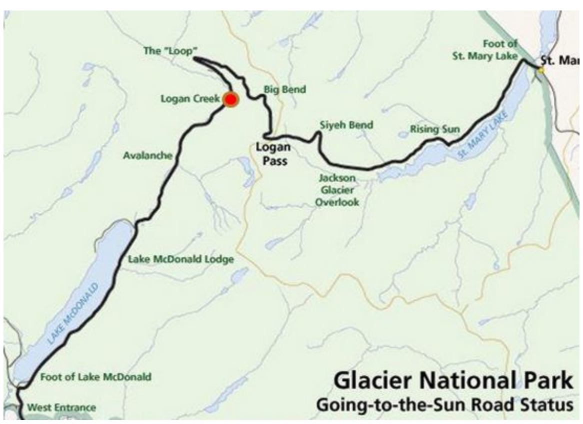
The visitor loops around again looking for a parking spot.



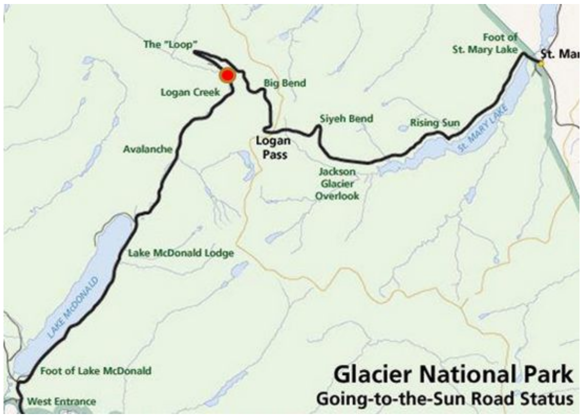
The visitor gives up on looking for a parking spot and decides to continue up towards the Loop.



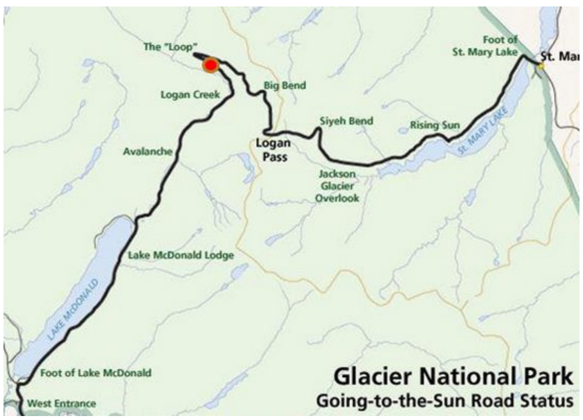
The visitor continues along the road towards the Loop.



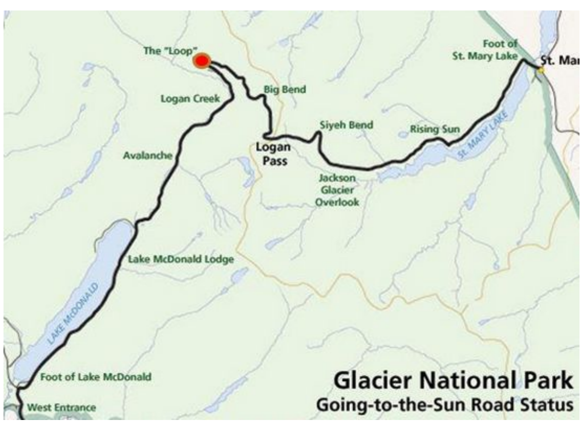
The visitor continues along the road towards the Loop.



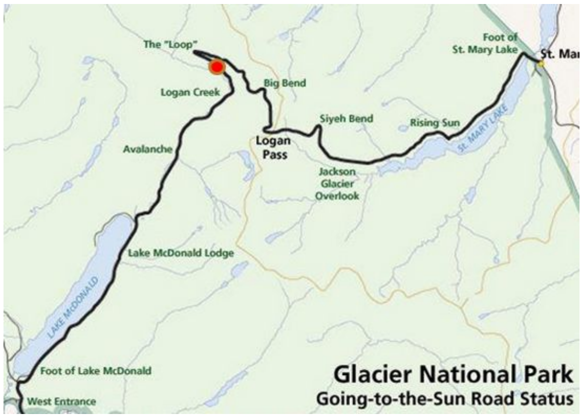
The visitor continues along the road towards the Loop.



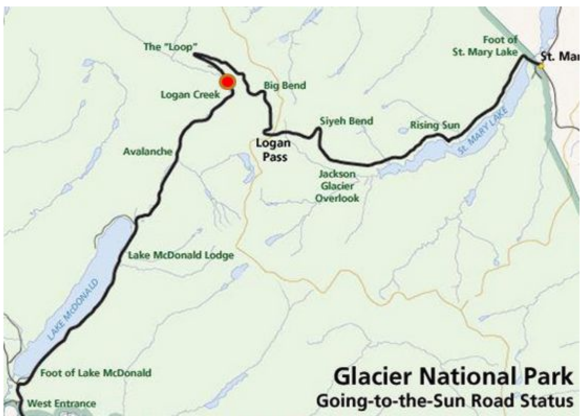
The visitor continues along the road towards the Loop.



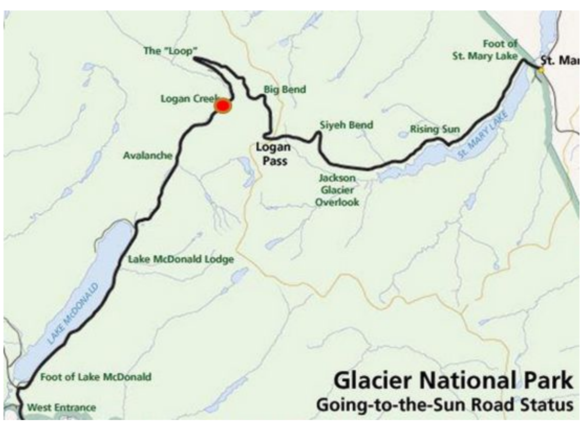
The visitor stops for about 15 minutes at an overlook on the Loop.



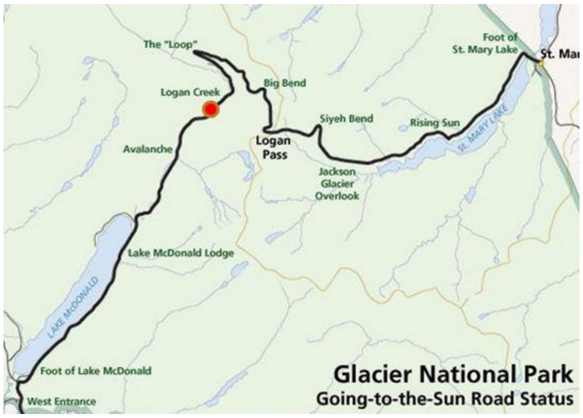
The visitor then gets back in their car and began driving back towards the entrance where they came in.



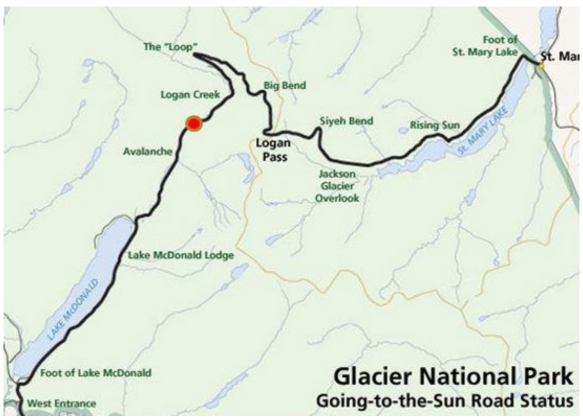
The visitor continues driving towards the West Glacier entrance.



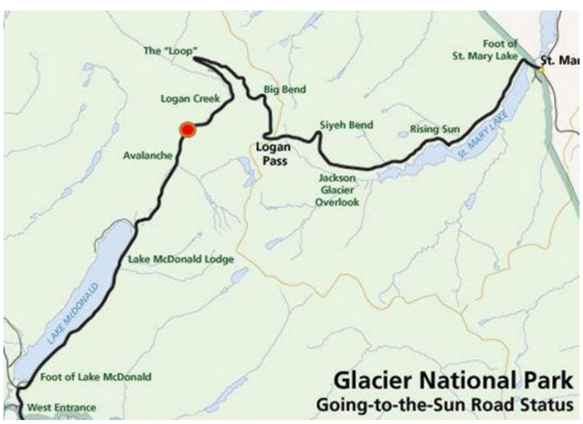
The visitor continues driving towards the West Glacier entrance.



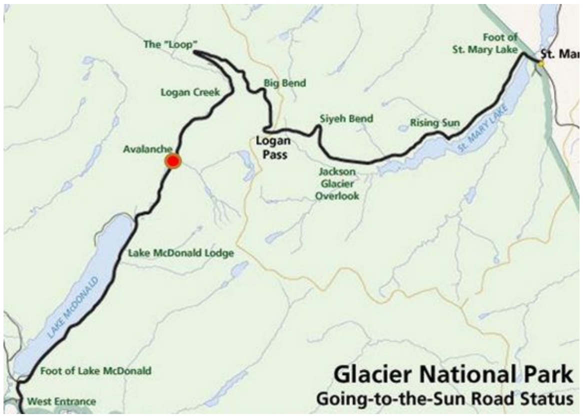
The visitor continues driving towards the West Glacier entrance. The visitor also hits some traffic due to congestion at this point.



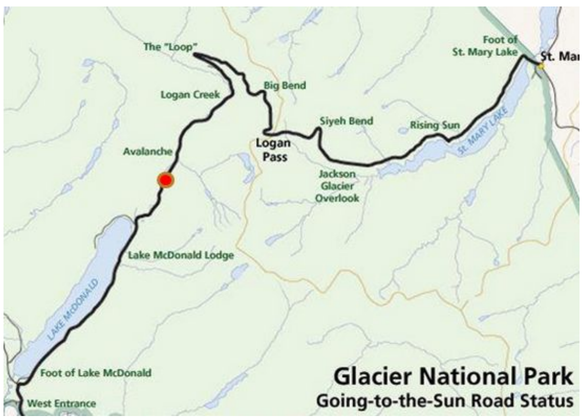
The visitor continues driving towards the West Glacier entrance in the congestion.



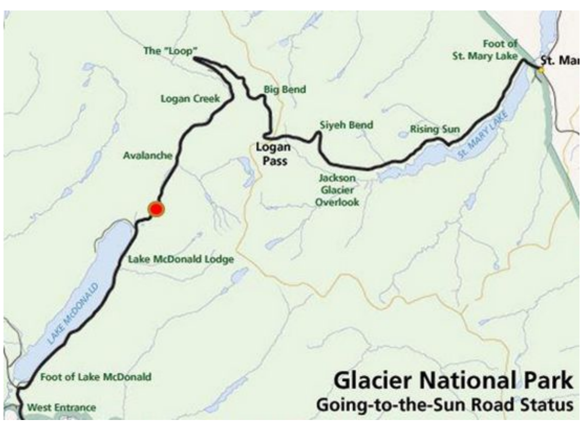
The road clears up and the visitor continues driving towards the West Glacier entrance at normal speed.



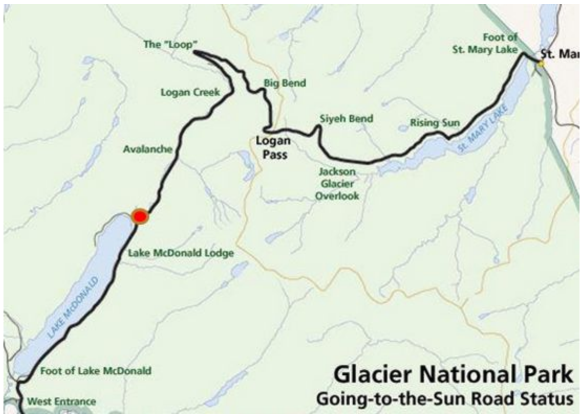
The visitor continues driving towards the West Glacier entrance.



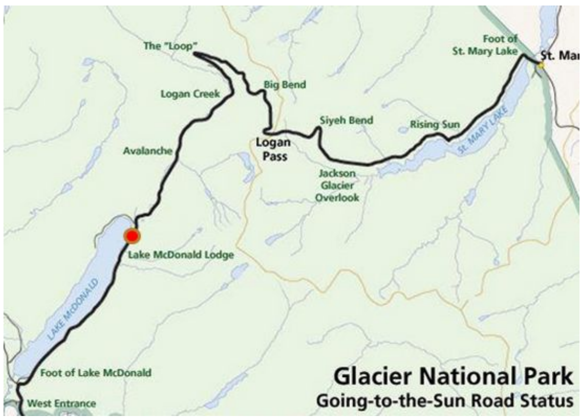
The visitor hits some more traffic, but continues driving towards the West Glacier entrance.



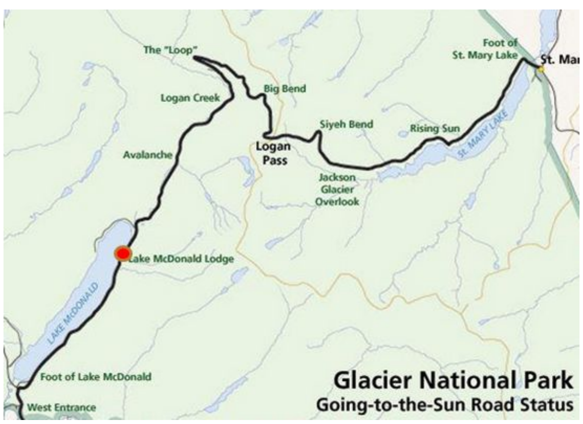
The visitor continues driving towards the West Glacier entrance.



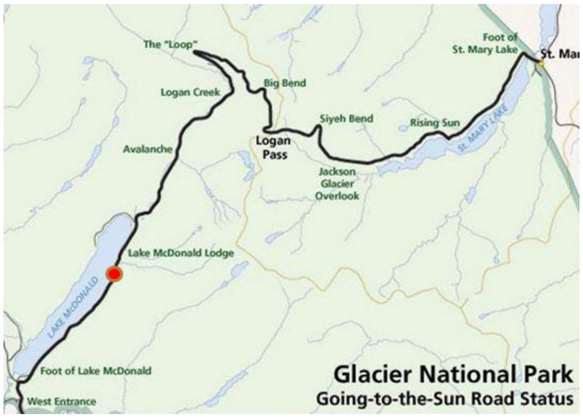
The visitor continues driving towards the West Glacier entrance.



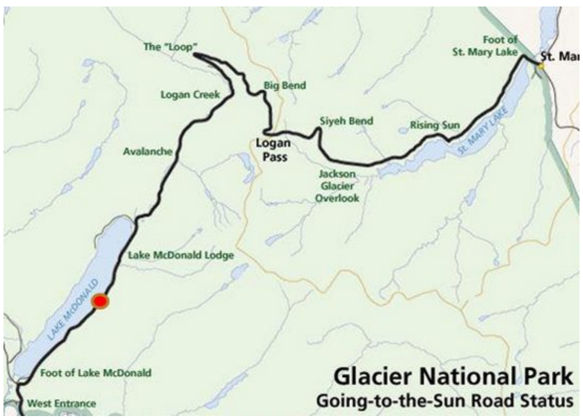
The visitor continues driving towards the West Glacier entrance.



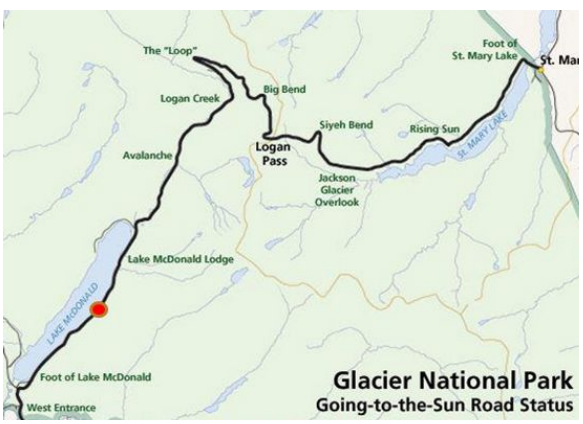
The visitor continues driving towards the West Glacier entrance. The visitor runs into traffic congestion again.



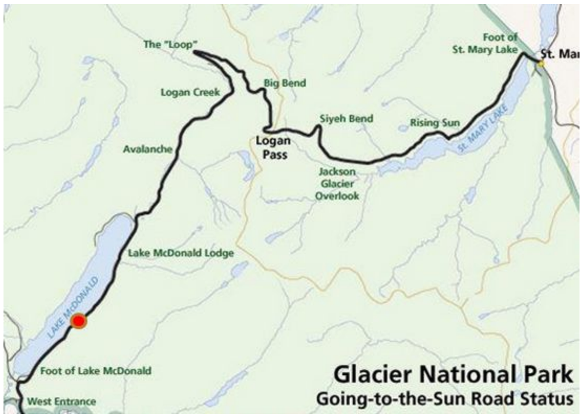
The visitor continues driving towards the West Glacier entrance.



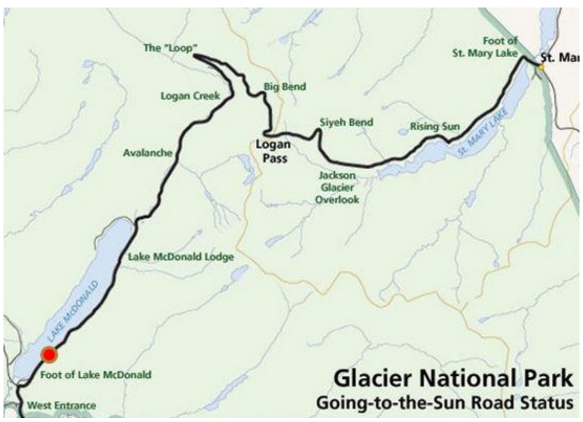
The visitor continues driving towards the West Glacier entrance.



The visitor continues driving towards the West Glacier entrance.



The visitor continues driving towards the West Glacier entrance.



Finally, the visitor exits the park out of the West Glacier entrance where they had originally entered the park.

Figure 33: Step-by-Step Single User Track Visualization, by Frederick Bianchi, 2019.

APPENDIX B: INTERVIEW QUESTIONS AND ANSWERS

1. What tool do we use to analyze data set?

a. There are a lot of software that can be used, but I would suggest excel because of its simplicity and numerous built in functions.

2. How should we handle potential outliers in the data?

a. It is important to look for outliers and consider potential reasons for them, however when analyzing the data if it doesn’t make sense, get it out of the picture.

3. What is the best way to visualize large amounts of data?

a. A good way to visualize large amounts of data is through charts and graphs. Because a lot of your data is non numerical I suggest a box chart.

4. What would be a good analytic tool to deal with large amounts of data?

a. One good way of working with data is to try and find correlations with data sets. When dealing with categorical variables it is not possible to find a numerical correlation so just try to find any relationship within these.

APPENDIX C: UML CLASS DIAGRAMS

Universal Modeling Language (UML) class diagrams enable developers to create a visual representation of all of the data classes in a software project. In object-oriented languages, such as Java, a class is a blueprint for a piece of data that represents a physical object. They contain any interactions the object will have with other objects or data types. In this model, each class is represented by a box consisting of three partitions: the class name and object information, the data fields representing the attributes of the class, and one containing any associated functions of the class (Bell, 2004). Class inheritance is represented by an upwards arrow pointing directly at the classes being inherited and can be dashed if importing an interface. This structure is also known as tree notation (Bell, 2004). Tree notation is useful when designing a new software project on paper, or validating the viability of an existing project.

We intend to use this technique to design and assess the viability of Speed Tracker, an open-source application that can be used for the basis of our Visitor Tracking application. Knowing the UML class diagram of Speed Tracker will allow us to refer to existing functionality of the application at a glance and will give us a blueprint that we can visualize to make any necessary modifications. We plan for one team member to research the Speed Tracking application and create a UML diagram. This way, teammates with or without programming knowledge can easily get acquainted with the structure of the application. UML will also give a visual representation of the final program for any future developers that intend to use the application.

APPENDIX D: USER STORIES

User stories are an approach for creating realistic design goals for an application. It is done by creating one-sentence statements describing a feature from the perspective of a user ("Writing Effective User Stories - Tech at GSA"). They mainly serve as a way to facilitate discussion during meetings. The content of the statements is not as important as the discussions created using these statements. Epics are user stories that cover functionality larger than what can be completed in one iteration of a piece of software. Epics can be split into multiple user stories to add more detail to tasks and to create short-term goals for the team. Additional conditions can also be added to make standards for a task to be completed (Cohn, 2019). We plan to incorporate user stories to plan the functionality of features for the visitor tracking application.

APPENDIX E: AGILE DEVELOPMENT METHODOLOGIES

The first widely used software development life cycle (SDLC) was the waterfall methodology. There are several steps in SDLC: requirement gathering, analysis, system design, object design, development and testing, release, and maintenance. The waterfall methodology requires that each step be taken sequentially with groups not being able to do multiple steps consecutively. The waterfall method is the most intuitive solution. However, it does not consider environmental variability and the human component of programming (Wong, 2019).

A rising development methodology is the Agile method. It diverged from the waterfall method, as described by the Agile Manifesto: "1. Value Individuals and interactions over processes and tools, 2. Value working software over comprehensive documentation, 3. Value Customer collaboration over contract negotiation, 4. Value responding to change over following a plan" (Beck, K. et al., 2001).

The Agile method is goal-oriented and allows for more variation within the project. A vision is created to set up the goals of the team. The next step in the agile development process is the architectural spike, the period of preparation before beginning to work on the project. Afterwards, the next step is a series of agile sprints. An agile sprint consists of all of the steps in a development life cycle as mentioned above, but condensed into a two to four week long period. At the end of the sprint, there should be a basic, working version of the final product. This process allows for much more variability and responsiveness during the project life cycle. If the requirements were to change halfway through the waterfall method, there would be no standard, organized way to respond to the changes. The nature of our project dictates that changes to the application design process will happen frequently as we still discover the nature of the problem that we hope to face (Wong, 2019).

APPENDIX F: UNIT TESTING

Unit testing is a process that happens during application development. A program is made up of many small tasks, that work together in intricate ways. When a program crashes, any number of these interactions could be the cause. Unit testing isolates each of these tasks and tests their functionality to quickly find the problem (Hamill, P. 2009). In our project, we will be using the white box method for unit testing. White box testing is used when the person testing the code, typically the software developer, knows how it was written so that changes can be made in real time (Wells, D. 2013). Additionally, unit testing has the advantage of being able to reuse code as the project increases in complexity after each iteration. We will be using JUnit testing suite to test the application. This is the best solution for our team because JUnit interfaces easily with Android Studio.

APPENDIX G: VISION STATEMENT

The future of Glacier National Park is dependent on visitors going to the park. Glacier is open for the enjoyment of visitors, therefore it is the goal of the National Park Service and Glacier to ensure visitors enjoy their stay. As tourism increases within the park, congestion increases. As more visitors come to Glacier, park officials need to adapt to deal with the increasing number of visitors.

Since 2010, the number of visitors has increased from about 2.2 million to 3.3 million in 2018. If this trend continues, the number of visitors will be about 5.5 million in 2025. Glacier is struggling with the current increase. A further increase in numbers will be even more difficult to manage. As more people go to Glacier, there will be even more cars and people in the park, creating more congestion issues. There is already a lack of amenities for current visitors, and with more visitors there would be even less access to amenities.

The increase in cars that comes with the increase of visitors is harmful for the park. The parking lots in Glacier were not made to handle the current amount of visitors, and visitors turn to parking on road shoulders once the parking lots overflow. Glacier's carbon footprint grows as more cars enter the park and idle on congested roads. These environmental changes can harm the wildlife, as their natural habitat is disturbed. Glacier will no longer be preserved, meaning the goal of the National Park Service will not be achieved.

Based on this trend, it will be necessary to implement a solution to preserve the park long-term. An ideal solution would be a monorail system, similar to that of Disney World, that eliminates cars all together. If there are no cars in the park, there will be no traffic congestion in the park. Guests will park at a parking garage located at the monorail origin station. The monorail will be put in place of Going-to-the-Sun Road, going from West Glacier to St. Mary. The monorail could also have different lines, similar to a subway system, added that would go where current roads in the park do not reach. The monorail will have different stops throughout the park, enabling visitors to get off at different stations to see each attraction.

The main benefit of the monorail is cars will be eliminated from the park. This will reduce the number of emissions from visitors within the park. Also, parking lots can be removed from the park, restoring the natural vistas. The monorail will also run on a timed schedule, meaning people will not have to worry about delays in travel time. It could also be powered by renewable energy sources to reduce the park’s carbon footprint.