An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

Evaluating Glacier National Park's 2021 Ticketed Entry System

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Abstract

Increased visitation in national parks has led to road and trail congestion, a decrease in overall visitor experience, and damage to some of the country's most treasured natural areas. National parks have developed many methods to both measure and mitigate visitor congestion. We evaluated the effectiveness of Glacier National Park's pilot Ticketed Entry System by interviewing park rangers and using a big data analysis platform, Streetlight Data, which allowed for analysis not available through traditional congestion measurement methods. Based on our results, we developed recommendations that aim to continue to smooth surges of visitor entries, maintain lower levels of main road congestion, and ensure the park remains accessible for all user groups in the future.

Increasing Visitation in National Parks

In 2019, over 327 million people visited national parks in the United States, an increase of 9 million visitors from 2018 (National Park Service, 2020). While increased tourism can have economic benefits for national parks and their surrounding communities, it can also have detrimental effects on the visitor experience, park staff, and environment. The surge of visitors "loving nature to death" has caused an increase in road and trail congestion, leading to additional trail erosion, resource damage, and pollution (Simmonds et al., 2018; Kim et al., 2018).

Glacier National Park (GLAC) has seen an increase in visitors, doubling in visitation since the turn of the century (National Park Service, 2021f). GLAC reached a peak of 3.3 million visitors in 2017, 1 million of which visited solely during the month of July (National Park Service, 2021f). *Figure 1* represents the increase in Park visitation over the past 60 years, illustrating a prominent peak in 2017, as well as the drop in visitation due to the Park's closure in response to the pandemic in 2020.

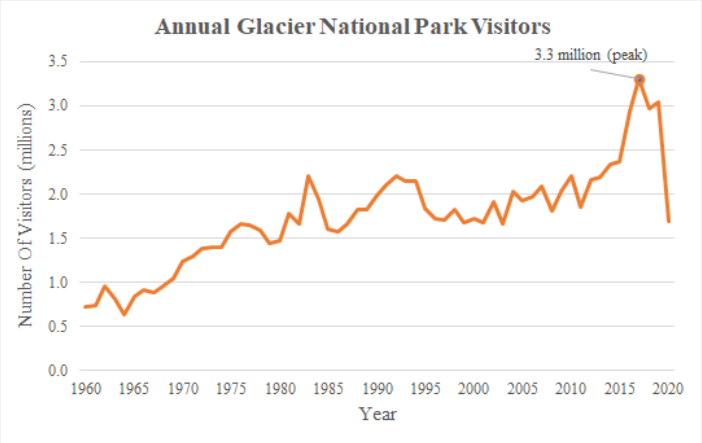

Figure 1. Number of visitors to Glacier National Park by year since 1960 (National Park Service, 2021f)

The Impact of Increased Visitor Congestion in Glacier National Park

Congestion along the Going-to-the-Sun Road (GTSR) is a major concern for the Park, and directly impacts the visitor experience. GLAC visitors contribute to congestion along the road when parking in pullouts or parking lots, and when slowing down to view the scenery and wildlife (National Park Service, 2019c). In attempts to alleviate this congestion and avoid gridlocking, GLAC has been forced to restrict visitor access along the GTSR and other areas frequently in the past. During the peak season in 2017, the Park restricted access to Many Glacier 26 times, Kintla Lake 52 times, and Bowman Lake 68 times (National Park Service 2019d). Parking lots have also frequently filled up quickly, especially the Logan Pass Visitor Center parking lot, pictured in *Figure 2*. This trend is seen in other national parks as well. Studies conducted in Yosemite found diminishing visitor experiences with an excess of congestion on roads (White et al., 2012; Whittaker et al., 2012).

Figure 2. Full parking lot on September 11, 2019 at Logan Pass Visitor Center in Glacier National Park (Scott, 2020)

The trails in GLAC have been congested as well. In 2017, the Hidden Lake Trail (a beginner level trail with access from Logan Pass Visitor Center parking lot) averaged 1,604 hikers each day (National Park Service 2019d). Additionally, ten of the most popular hiking trails in the Park "all average[d] hundreds of hikers per day," (National Park Service 2019d). A study conducted in Great Smoky Mountains National Park found that too many people on the trails negatively influenced their experience, as they felt crowded "like cattle" until they got "further up… away from the groups of people" (Dorwart et al., 2009).

Increased use of hiking trails in national parks also has negative impacts on the environment, such as path widening, trail erosion, increased informal

(visitor-created) trails, vegetation trampling, and presence of litter and human waste (National Park Service, 2019c). It is a priority of the National Park Service to protect their natural ecosystems and wildlife, yet increased tourism within GLAC threatens this.

The increased number of visitors has put a strain on the park staff, especially when hikers come unprepared for their journey. As of July 9th, 2019, GLAC law enforcement activity and emergency incidents increased by 40% from 2018 to 2019 (National Park Service, 2019a), which emphasizes the importance of keeping the GTSR open to allow for emergency vehicle access (Murray, 2019).

Conversely, increased tourism to GLAC benefits the economy of the Park and its surrounding communities. In 2014, the 2.3 million visitors to GLAC spent a total of $193 million in communities near the Park, supporting over 3,000 jobs in the local area (National Park Service, 2015). According to a 2016 survey, local area spending per visitor group ranged from $54 per day (local resident spending) to $400 per day (non-local park visitors) (National Park Service, 2019c). Despite these economic benefits in the surrounding areas, GLAC has taken several approaches to avoid overwhelming congestion within the Park.

Methods to Mitigate Congestion

Large parks and tourist attractions use various methods to mitigate congestion and communicate conditions of congestion to visitors. These strategies include signage, ticketing for traffic violations, shuttle services, use of social media, expansion of infrastructure, and reservation systems. These strategies are initially proposed through park specific management plans, such as the GTSR Management Plan established for GLAC in 2019. These strategies are triggered when indicators such as vehicles at one time (VAOT), persons observed at one time on trails, and infrastructure carrying capacities reach a certain threshold (National Park Service, 2019c). In national parks, indicators and thresholds for visitor use are currently monitored on-site by park staff through various ways of congestion measurement (National Park Service, 2019c). These mitigation strategies have different functions and impacts, which we offer a comparison of in *Table 1.* (See Appendix A Supplemental Materials for a more detailed explanation of each mitigation strategy.)

Table 1. Comparison of mitigation strategies (Barrameda et al; National Park Service, 2019c)

Aspects / Strategy	Frequency of Use	Low-cost Implementation	Feasible for Park Staff to Implement	Mitigated Congestion Variables	Successful at Mitigating Vehicle Congestion	Obstacles
Signage	High	Yes	Yes	- VAOT - Persons observed at one time	Yes	Signs/cones could be missed or ignored
Traffic Violation Tickets	High	Yes	Yes	- VAOT in undesignated areas	No	Ticket costs don't always deter illegal parking
Shuttle Services	High	No	Yes	-VAOT	Yes	Many visitors may choose to drive personal vehicles
Social Media	High	Yes	Yes	- VAOT - Persons observed at one time	Unknown	Visitors must check social media platforms
Expansion of Infrastructure	Low	No	No	- Carrying Capacities	Yes	Construction degrades Park environments
Reservation Systems	Moderate-typical during peak seasons	Yes	Yes	- VAOT - Persons observed at one time	Yes	The Park could lose profit by limiting visitors

In the past, GLAC has implemented a variety of these mitigation strategies to control congestion in the Park. However, with increasing visitation to the Park and rising concerns of gridlocking and traffic backups along the GTSR and U.S. Highway 2, GLAC implemented a ticketed entry system from May 28st to September 6th, 2021. This system limited entry tickets to 4,600 vehicles per day while parking along the GTSR only offers 2,100 parking spots (Peterson, 2021). Reservations were necessary to enter the GTSR from both the West and Saint Mary Entrances. The system required visitors to create an online account at Recreation.gov and pay a $2 transaction fee (National Park Service, 2021a). 75% of reservation tickets were released 60 days in advance, while the remaining 25% of tickets were released 2 days in advance (National Park Service, 2021a). Tickets were valid for a 7 day period and were not necessary for visitors who chose to hike or bike the road, which offered an incentive for visitors to use alternative transportation (National Park Service, 2021a).

Methods to Measure Congestion

To understand where and how to best mitigate congestion, park staff collect data about visitors. Visitor mobility data is defined as data that pertains to visitors' activity and contains both a spatial and temporal element (Managing Mobility Data, 2019).

Cruise ships, museums, and national park services have used many methods to collect visitor mobility data, including car and trail counters, webcams, and GPS tracking devices and applications (Clavi et al., 2017; Ferrante et al., 2018; Jemison et al., 2019; Zheng et al., 2017). Each of these data collection methods yields a different type of data and has unique abilities and limitations. *Table 2* summarizes these differences.

GLAC has used a combination of trail counters, car counters, webcams, and GPS tracking apps to collect mobility data. Together these methods have given the Park an estimated visitation total and

Table 2. Comparison of traditional mobility data collection methods. (Clavi et al., 2017; Ferrante et al., 2018; Jemison et al., 2019; Zheng et al., 2017)

Criteria	Car/trail counters	Webcams	GPS Tracking
Volume of Data Available	Based on number of car/trail counters	Based on number of webcams	Based on number of visitors with tracking app and/or carrying devices
Hardware Needed	Counter devices	Webcam systems (cellular)	No park-installed hardware required
Cost	Hardware Low operation cost	Hardware Low operation cost	Hardware or app costs Low operation cost
Data Accessibility	Stored locally in the park	Images available online	GPS coordinates can be exported
Effort of the Participants	None	None	Must consent to data tracking and turn on/off tracking
Interruptions of Visitor's Day	None	None	Must collect a GPS device or download a GPS app
Accuracy	Trail counters have some inaccuracies, car counters rely on an estimated people per vehicle factor	Camera footage: requires software or manpower to count cars	Occasional inaccuracies in GPS coordinates

an understanding of traffic patterns, but they are limited in their ability to capture the full scope of congestion within the Park and its surrounding areas. For example, car counters and webcams can only record data in specific, predetermined locations. GPS tracking apps can track visitors throughout the Park, but they rely on visitor participation and cannot acquire enough data to draw meaningful conclusions about traffic patterns (Barrameda et al., 2018).

Big Data for Visitor Mobility Analysis

Advanced methods of mobility data collection have emerged that are hardware independent and make use of big data. Big data refers to extensive datasets which cannot be managed or analyzed by traditional methods such as volunteer surveys (SAS Institute INC, 2018; McAllister, 2010). With big data sets, patterns and projections are much easier to visualize and analyze (Jiang et al., 2016). Further methods to analyze and visualize datasets can be seen in Appendix B. In the analysis of any dataset, including big data, it is paramount to consider the effects of data bias on analysis (Appendix C).

Streetlight Insight (SLI) is an on-demand web platform for transportation data. It tracks, collects, and analyzes big data regarding vehicular traffic for different modes of transportation across the United States and Canada (Streetlight Data, 2019). SLI collects data from location-based services (LBS) on cellular devices and GPS systems within vehicles and on cell phones (as shown in *Figure 3*). LBS does not require cellular connectivity to transmit data (Streetlight Data, 2019). SLI's machine learning algorithms take these pings and connect them to produce a likely trip that a vehicle has taken. These trips are compiled and stored in a large data set that can be explored through several types of SLI analyses. SLI also uses algorithms to determine the mode of traffic for each trip. Through connections of LBS and GPS points combined with census data, SLI supplies several different trip metrics such as vehicle type, trip speed and purpose, demographic information, and more. State transportation departments, consulting firms, and private corporations have all used SLI to conduct traffic studies, resulting in over 6,000 transportation projects per month (Streetlight Data, 2019).

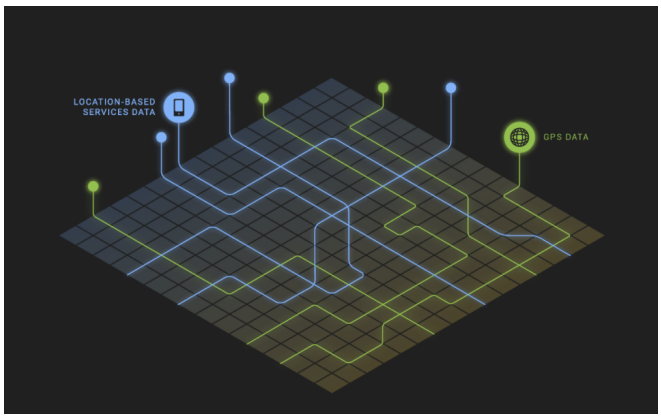

Figure 3. A visualization portraying how Streetlight Insight collects mobility data

SLI is widely used in city planning, but it has also been applied to national parks and protected areas. A study was conducted in Orange County, CA, that assessed the usefulness of Streetlight Insight in parks and protected areas. It found that SLI estimated traffic volumes within 5.7% of manual counters and suggested similar traffic trends (Monz et al., 2019).

SLI can provide a large volume of mobility data from areas throughout the Park, does not require visitor participation, and contains data from as far back as 2017. When combined with traditional mobility data collection methods, SLI can provide a more complete analysis of visitor patterns in areas such as Glacier National Park.

Methodology: Evaluating the 2021 Ticketed Entry System

The goal of this project was to use Streetlight Insight to evaluate the effectiveness of the 2021 Ticketed Entry System on minimizing congestion within Glacier National Park. We also determined the impacts of the Ticketed Entry System on traffic patterns both in and around the Park. In order to achieve our goal, we developed five objectives that are detailed below.

Compile Information	Streetlight Insight Analyses	Conduct Interviews	Evaluate the 2021 TES	Provide Recommendations
• Congested areas in GLAC • Existing mobility data	• West Entrance • Going-to-the-Sun Road • Surrounding Communities	• Ma'ayan Dembo • Park Rangers	• West Entrance • Going-to-the-Sun Road • Valleys • Surrounding Communities	• Park Administration • Further Research

Objective 1

Compile information on congested areas within Glacier National Park and acquire existing data on visitor mobility.

First, we synthesized information collected from our background research and quantitative data from the Park provided through our sponsors, Mary Riddle and Tara Carolin, to identify areas of focus for conducting our analyses.

Specifically, we acquired inductive loop car counter data available on Integrated Resource Management Applications Portal (IRMA) for all years since 2000 (available for individual months) for locations including Camas Road, Goat Lick, Many Glacier, Polebridge, St. Mary Entrance, Two Medicine, and the West Entrance. We also gained information from inductive loop car counter data for 2019 and 2021 (available for individual days and hours) at locations including West Entrance, St. Mary Entrance, and Camas Road Entrance. This data also includes the calculated VAOT along the GTSR from the entrance and exit car data (west side entrances, east side entrances, and the full GTSR) for 2019 and 2021 (available for individual days and hours).

We acquired radar car counter data for the 2021 season (available for individual days and hours), and the Park had access to pneumatic car counters from the University of Montana for several years, however, the accuracy of these car counters differ from those of inductive loop counters. To maintain consistency across years for corroborating our acquired data, we used data collected from the inductive loop car counters.

Table 3 lists the areas of focus which are park entrances, the most popular road (GTSR), the most popular parking lot (Logan Pass) and major destinations outside of the Park.

Table 3. Areas of focus for our analyses, within and outside of GLAC

Areas *Within* Glacier National Park	**Areas *Outside* Glacier National Park**
• Logan Pass Parking Lot • Going to the Sun Road • West Glacier Entrance • Apgar Village • St. Mary Entrance • Two Medicine • North Fork • Many Glacier	• Hungry Horse • Coram • Columbia Falls • Whitefish • Kalispell • Martin City • Lakeside • West Glacier

Objective 2

Use Streetlight Insight to run analyses and obtain quantitative data regarding key areas within and outside the Park.

We used Streetlight Insight (SLI) to perform analyses on the key areas of the Park that we defined in objective 1. We ran analyses on these areas for 2017, 2018, 2019, and 2021 in order to identify differences in travel patterns and visitor demographics before and after the implementation of the Ticketed Entry System (TES).

Before performing our analyses, we interviewed a WPI student that used SLI for a Visitor Mobility Analysis project in Acadia National Park. Through this interview, we were able to gain a more comprehensive understanding of the software and identify possible limitations in the context of our proposed project (See Appendix D, Supplemental Materials).

We ran analyses for the date range of June 22nd through August 15th for each year. We chose these date ranges because during this time period, the GTSR is usually completely open, and in 2021 the TES was in place. We chose August 15th as the end date because SLI has only provided data for 2021 up to that date (NOTE: Data from August 1st to August 15th, 2021 was listed as "preliminary").

We used three types of Streetlight analyses: Origin-Destination Analysis, Segment Analysis, and Zone Activity analysis. (For detailed descriptions of each analysis, see Appendix E Supplemental Materials). *Table 4* lists and describes the primary analyses that we performed.

Objective 3

Acquire qualitative data pertaining to the impacts of the Ticketed Entry System in and around the Park.

In addition to our quantitative data, we obtained qualitative data through semi-structured interviews. We interviewed four Park rangers stationed throughout the Park at the West Entrance, North Fork, Two Medicine, and Many Glacier (See Appendix D, Supplemental Materials for interview questions).

We acquired qualitative data in addition to quantitative data for four reasons:

1. **Confirm quantitative data.** Observations about traffic and movement patterns from Park staff helped to either confirm quantitative data or flag data as potentially inaccurate. This let us know that we needed to look closer into our SLD Analyses.
2. **Collect data on the perception of congestion.** Quantitative data cannot provide insight into the perception of congestion, which may differ from actual congestion. Visitor perception varies, and is dependent on numerous factors. The perception of congestion is an important metric because it relates to the visitor experience (Dorwart et al., 2009).
3. **Understand the visitor perspective.** Speaking with Park staff, who interacted with visitors all summer, gave us insight into potential reasons for pattern changes that we

Table 4. Description of specific SLI analyses used for our project

Analysis	Purpose
Origin-Destination Analysis of GTSR	To determine the most popular places along the road, average speed of vehicles, trip volumes across segments, trip durations, exit times
Segment Analysis of GTSR	To determine the distribution of congestion and vehicle speeds along the road
Origin Destination Analysis from Ticket Corral (where visitors w/o a ticket were turned away) to key surrounding communities	To find where visitors went after being turned away at the Park
Zone Activity Analysis of Ticket Corral	To find vehicle counts of those who traveled through the Ticket Corral
Zone Activity Analysis of West Entrance with Home/Work Locations	To determine entrance times as well as visitor home states

observed from our quantitative analyses. This helped us to draw conclusions about the effectiveness of the TES from a visitor perspective.

4. Gather criteria for what makes the TES successful. Through interviews with Park staff, we gained an understanding of how the TES affected all areas of the Park**.** This gave us context in which to frame our quantitative data, and helped us to both organize and prioritize our findings.

Objective 4

Evaluate the effectiveness of the 2021 TES using comparative analysis of congestion at the West Entrance, the GTSR, and the Park Valleys for 2019 and 2021.

To evaluate the effectiveness of the 2021 TES, it was necessary to understand the initial goals of the system and the perspective of park staff on its impacts.

We learned the initial goals of the TES through conducting a semi-structured interview with Ma'ayan Dembo, Transportation Fellow and member of the Congestion Management Working Group in GLAC. We gained a preliminary understanding of the Park staff's perspective of the effectiveness of the TES through semi-structured interviews with park rangers stationed around the Park. We interviewed rangers stationed at the West Entrance, North Fork, Many Glacier, and Two Medicine in order to provide a comprehensive overview of the Park and the impacts of the 2021 TES.

With the SLI analyses run previously, we were able to evaluate changes in Park congestion levels from 2019 and 2021. We exported SLI analytics into Excel and created comparative graphs and tables to demonstrate the differences in several metrics over the years. From these comparative analyses we ran in objective 2 and corroborative data from Park Ranger interviews conducted in objective 3, we could then draw conclusions on the effectiveness of the TES for each area of the Park.

Objective 5

Make recommendations on how to proceed with future TESs.

After evaluating the effects of the 2021 TES through SLI analyses and interviews with park rangers, we developed recommendations for further research projects and how GLAC administration could adjust the TES for future years.

Results and Recommendations

In June of 2020, Glacier National Park considered implementing a reservation system as a method of ensuring public health during the COVID-19 Pandemic. The Park did not go through with this plan because there was not enough time to effectively communicate plans to potential visitors. GLAC was not able to open the East Side entrances in 2020 (including St. Mary, Two Medicine, and Many Glacier). As a result, GLAC had to close the West Entrance and portions of the Western GTSR 28 times (M. Dembo, personal communication, Sept. 22, 2021).

Going into 2021, the Park knew they needed to develop a better strategy to manage visitors. GLAC created a pilot 2021 Ticketed Entry System, which required visitors to purchase an entry ticket to travel the Going-To-The-Sun Road (GTSR) between the hours of 6 AM and 5 PM from May 28th until September 6th. There were 4,600 entry tickets available for each day, and each ticket was valid for 7 days. 75% of the tickets for each day became available 60 days in advance, with the remaining tickets being reserved for purchase two days in advance (National Park Service, 2021e). Visitors that arrived at a GTSR entrance without an entry ticket were turned around and directed to either return after TES hours or to visit an area that did not require an entry ticket such as Two Medicine, North Fork, or Many Glacier (M. Dembo, personal communication, September 22, 2021). *Figure 4* is an overview of the GLAC Headquarters Ticket Corral for 2021.

According to Ma'ayan Dembo, Transportation Fellow and member of the Congestion Management Working Group, the main goals of the 2021 Ticketed Entry System were to (1) reduce West Entrance visitor congestion, (2) provide entrance certainty for visitors entering the Park, (3) improve visitor use management throughout the Park, (4) set visitor expectations for congestion and construction delays, and (5) to reopen the East Side entrances.

Through our quantitative and qualitative analyses, we found that the **2021 TES reduced the volume of vehicles along the GTSR and reduced congestion during peak hours of operation. It redistributed the vehicle load spatially and temporally but, in doing so, caused unanticipated consequences for park staff and other locations in the Park.**

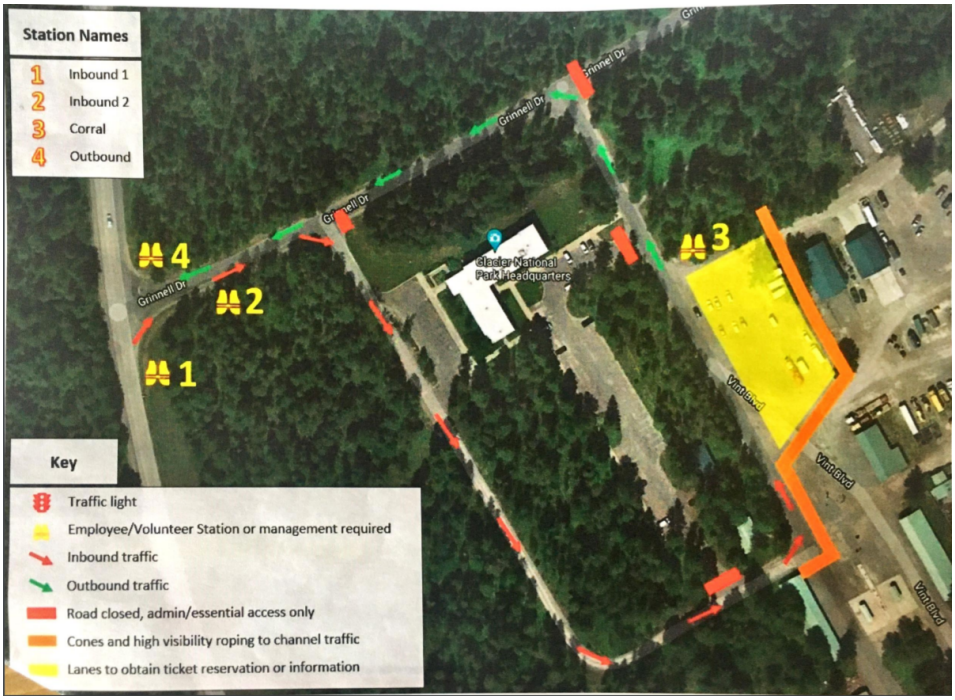

Figure 4. A visual representation of the GLAC Headquarters Ticket Corral procedure. There are staff stations, as indicated by the numbered vests. If visitors do not have a ticket, staff direct them into Park Headquarters. They wait in the Ticket Corral for a staff member to provide information on the TES. They then leave, taking a left on the GTSR, leading back to West Glacier.

We discuss the successes and unanticipated consequences of the 2021 TES below. We also offer recommendations to address these unanticipated consequences. We organized this section into five areas where we discovered impacts of the 2021 TES: the West Entrance, the Going-To-The-Sun Road, the Valleys (North Fork, Many Glacier, and Two Medicine), surrounding communities, and the overall visitor experience.

For each of the following Streetlight Insight analyses, we include a metric called "trip count." This is a measure of the approximate number of trips that are included in a data set. One trip does not correlate to one vehicle, as some vehicles may have more than one active GPS or LBS device, and some vehicles may not have any.

Redistribution of Congestion at the West Entrance

The 2021 TES temporally redistributed visitors, resulting in two additional peak times prior to and following TES hours. It also reduced the total volume of vehicles entering the Park, and resulted in later exit times from the Park.

SLI's Zone Activity analysis on the West Entrance revealed that 35% of Park entrances occurred outside of the TES hours in 2021, compared to 12% of Park entrances that occurred during those hours in 2019. The data in *Figure 5* represents the percentage of vehicles that entered the Park through the West Entrance for 2019 and 2021, broken down by hours, averaged across all days of the week.

While GLAC reported an overall decrease of 12% in vehicles on the GTSR in 2021 compared to 2019, the number of vehicles entering the Park through the West Entrance was reduced by 9.7% (approximately 30,000 cars) across June, July, and August of 2021 (National Park Service, 2021d; National Park Service, 2021f). Our analysis of the Ticket Corral system revealed that **the Park turned away approximately 19% of vehicles entering GLAC at the West Entrance.** Since the West Entrance was never closed in response to excessive congestion for the duration of the 2021 TES, the Park only needed to turn away visitors who attempted to enter without an entry ticket. *Figure 6* represents the percentage of trips through the Ticket Corral out of the total Park entry attempts, broken down by hour for all days of the week. The data in *Figure 6* highlights a peak of Ticket Corral entrances at 10 AM.

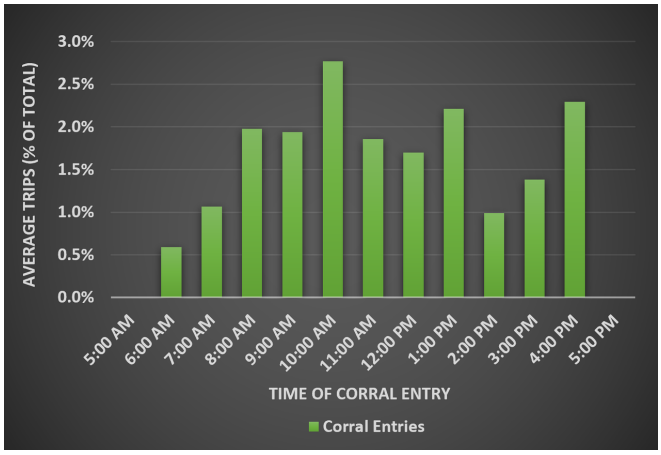

Figure 6. Trips that went through the Ticket Corral (out of total park entries), and adjusted to account for daily GLAC staff activity. The analysis used included a trip count of approximately 4000. (Source of Data: SLI)

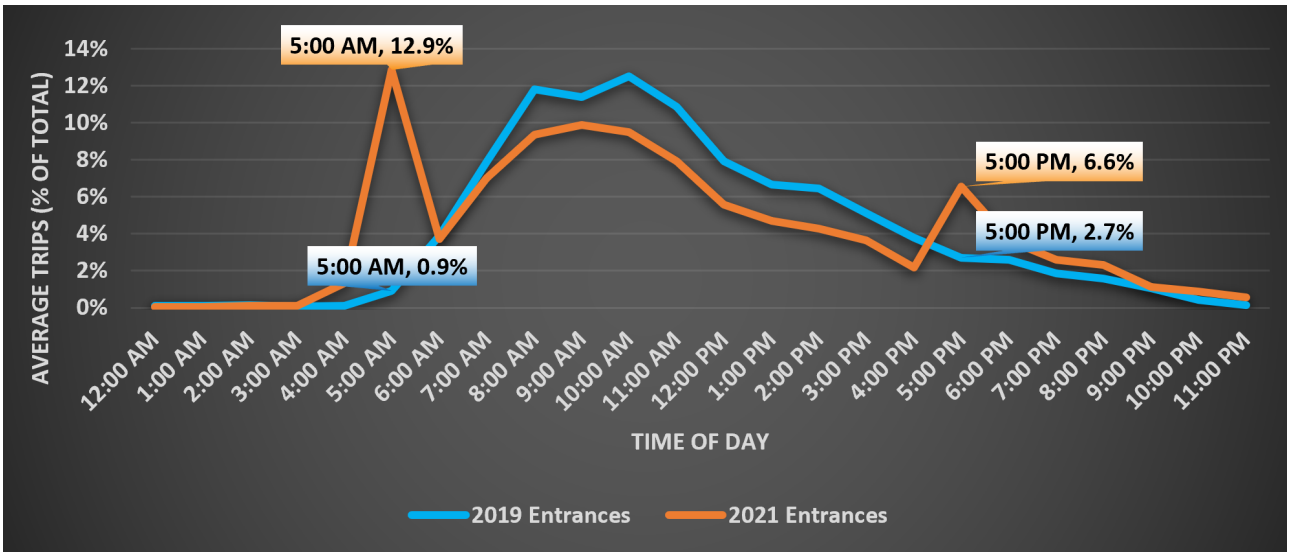

Figure 5. Total entrances through the West Entrance for 2019 and 2021. The analysis used included trips counts of approximately 5000 (2021) and 7000 (2019). (Source of Data: SLI)

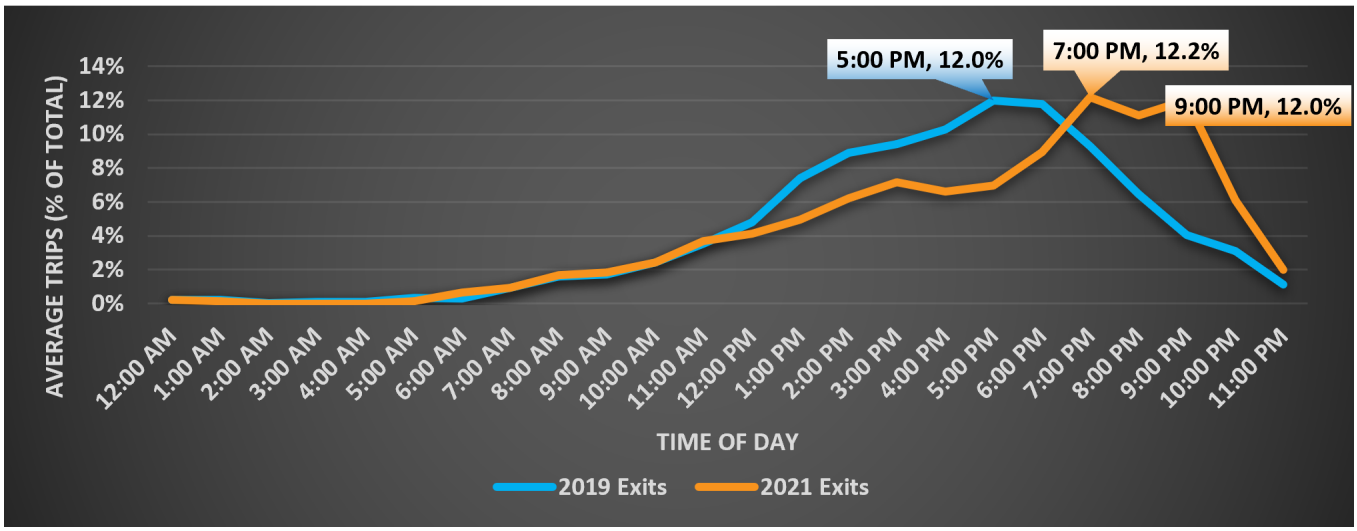

Figure 7. Percentage of vehicles that exited the Park through the West Entrance for different times of the day in 2019 and 2021. The analysis used had a trip count of 2000 (for 2019 and 2021). (Source of Data: SLI)

We observed later exit times in 2021 than in 2019, with peak exit times in 2021 being around 7 PM to 9 PM, compared to the peak exit times from 5 PM to 6 PM in 2019. *Figure 7* represents the percentage of vehicles that exited the Park through the West Entrance for 2019 and 2021, broken down by hour, for all days of the week.

While the TES was successful at reducing and dispersing Park entrances at the West Entrance, the introduction of the TES required a large portion of West Entrance rangers to be on site at the gate. Ranger Operations Coordinator Micah Alley explained how West End Rangers had to inform visitors about the TES, guide those without entry tickets through the Ticket Corral at GLAC Headquarters, and provide suggestions to ticketless visitors on how to proceed with their day at the Park. Alley stated that the demand for staffing created by the TES was overwhelming. He expressed that with "the same level of staffing as [in] 1980," rangers had already been overloaded by regular responsibilities, and now faced the challenge of ticketed entry on top of that. **The need for ranger presence at the West Entrance between 6 AM and 5 PM meant that there were fewer staff available to perform other routine and necessary tasks.**

Recommendation: Extend TES Hours (4 AM to 7 PM)

Since 35% of visitors entered the Park before 6 AM or after 5 PM, we recommend the park administration pilot extending TES Hours to begin at 4 AM and end at 7 PM. While we do not have sufficient evidence to conclude that extending TES hours would reduce the number of people trying to enter prior to or after hours, we do have evidence that shows 6 AM was not early enough to discourage this behavior. Similarly, 5 PM was not late enough to discourage visitors without a ticket from entering the Park. As part of this pilot program, administration should pay close attention to any increases of strain on park staff, especially because extending hours of the TES could require additional staffing at the gates.

Impact of TES on Going-To-The-Sun Road Congestion

The TES reduced average congestion along the GTSR. Gridlocking was prevented, and the road never had to be closed when the TES was active. **While average congestion decreased, some sections of the GTSR faced increased congestion as compared to previous years.**

Using the congestion metric in SLI, we identified the top five most congested areas during the peak seasons of 2019 and 2021. SLI has a built-in

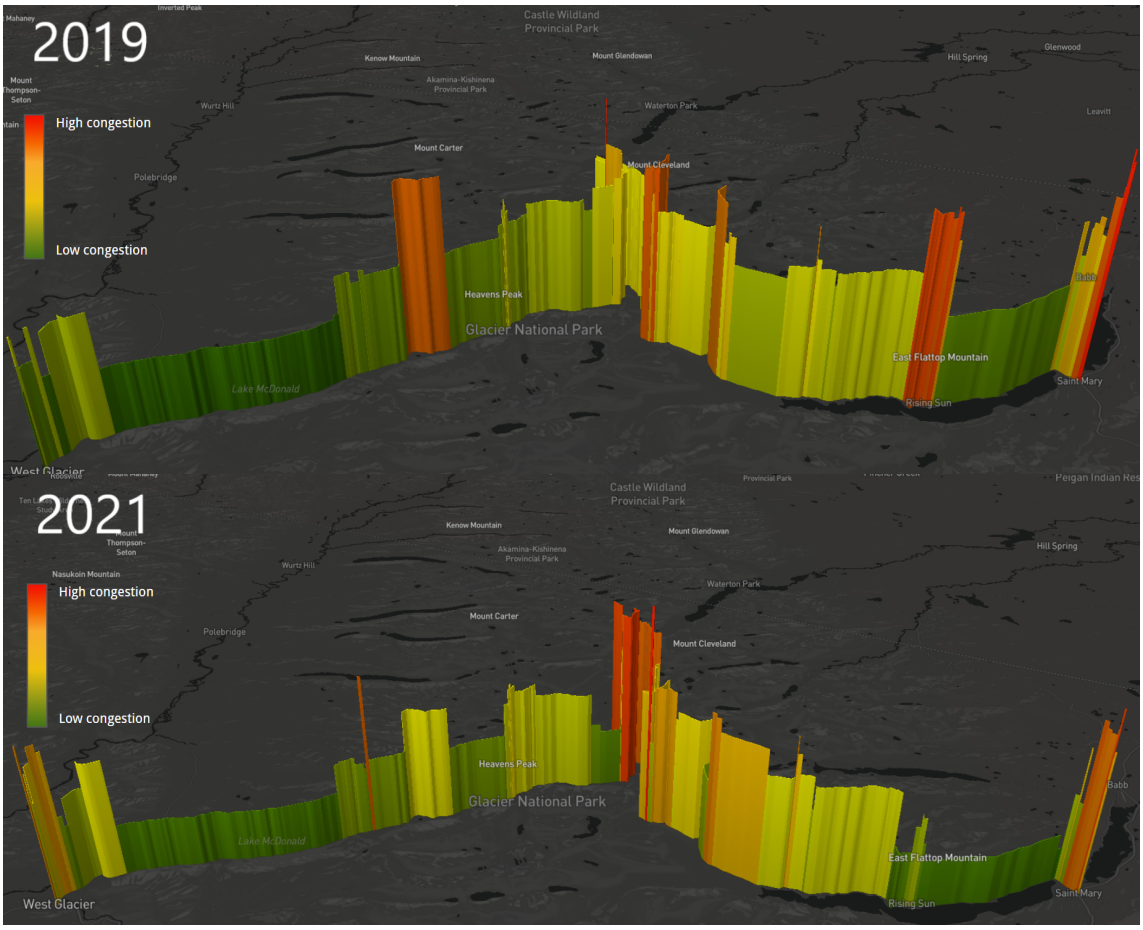

Figure 8. Varying congestion levels along GTSR for both years. The red segments indicate higher levels of congestion, and green segments indicate lower levels of congestion. The analysis used included trips counts of approximately 23,000 (2021) and 33,000 (2019). See Supplemental Materials for a further breakdown of congestion for each year. (Source of Data: SLI)

congestion metric, which compares the average speed of a particular segment to its maximum average speed. Therefore, if the average speed on a segment is much lower than the maximum recorded speed along the same segment, this would indicate a higher level of congestion. The congestion metric does not take vehicle volume into account. Congestion along the entire GTSR for 2019 and 2021 is shown in *Figure 8*. See Supplemental Materials (Appendix E) for more details. *Table 5* lists the top five most congested sections of GTSR for 2019 and 2021. **Areas such as the road near Logan Pass and the Loop were more congested in 2021 while other areas of the road, such as along Lake McDonald, were less congested.**

The road near Logan Pass was notably more congested than other segments of the road in 2021. To further investigate this, we used SLI to determine the times that vehicles were arriving at the Logan Pass Visitor Center parking lot. We found that the entrance times to the parking lot were

Table 5. The top five most congested segments of GTSR for 2019 and 2021. (Source of Data: SLI)

Top Congested Areas of GTSR 2019	Top Congested Areas of GTSR 2021
1. Baring Creek Bridge	1. Logan Pass
2. St. Mary Lodge	2. Logan Creek Bridge
3. Divide Creek	3. St. Mary Lodge
4. Rose Creek	4. The Loop
5. Rose Creek to Rising Sun	5. St. Mary Entrance

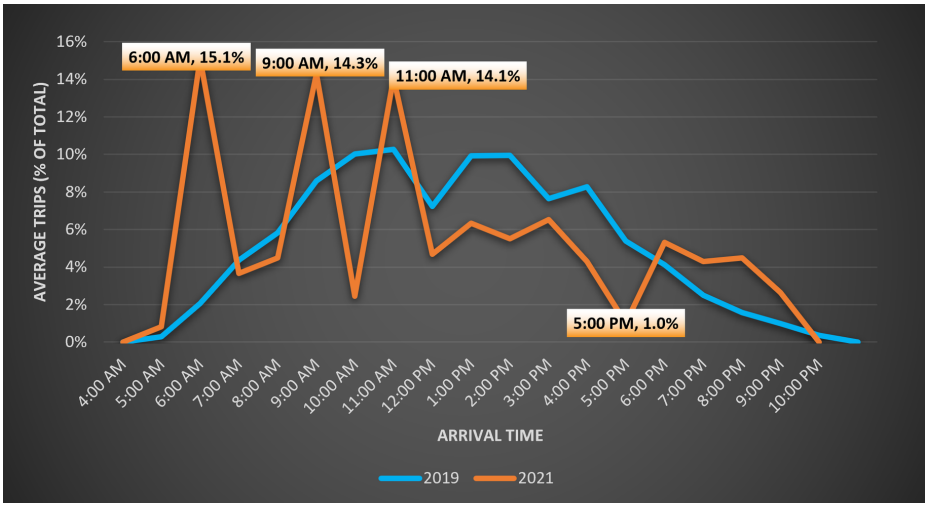

Figure 9. Distribution of arrival times to Logan Pass Visitor Center parking lot for 2019 and 2021. The analysis used had a trip count of approximately 1000 (Source of Data: SLI)

vastly different in 2021 as compared to 2019. *Figure 9* displays the average arrival times to the Logan Pass Visitor Center parking lot for the peak season of 2019 and 2021.

There are observable peaks in arrivals at the parking lot at 6 AM, 9 AM, and 11 AM. These peaks line up with the peaks we observed at the West Entrance; for example, visitors that enter the Park around 5 AM will likely reach Logan Pass Visitor Center after 6 AM. Overall, **2019 has a more even distribution of arrival times to the Logan Pass Visitor Center parking lot compared to 2021.** We can conclude that during TES hours, arrival times to Logan Pass Visitor Center parking lot were much more concentrated.

We also investigated the road alongside the Logan Pass Visitor Center parking lot. To compare congestion along this segment, we used the average speed in 2019 and 2021.

Figure 10 shows the segment of the road near Logan Pass that we analyzed. *Figure 11* displays the average speed in this segment for different times of the day.

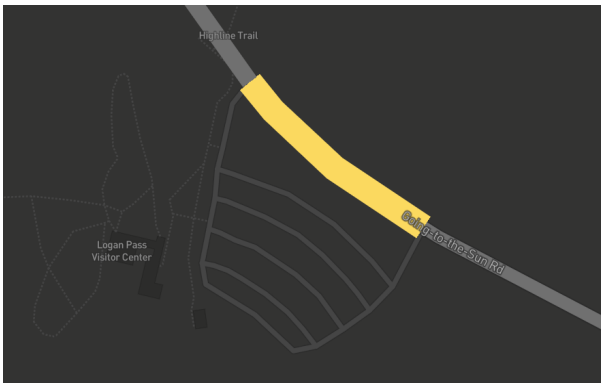

Figure 10. Logan Pass road segment on the GTSR used in the below analyses. Trip count of greater than 10,000 for both 2019 and 2021. (Source of Data: SLI)

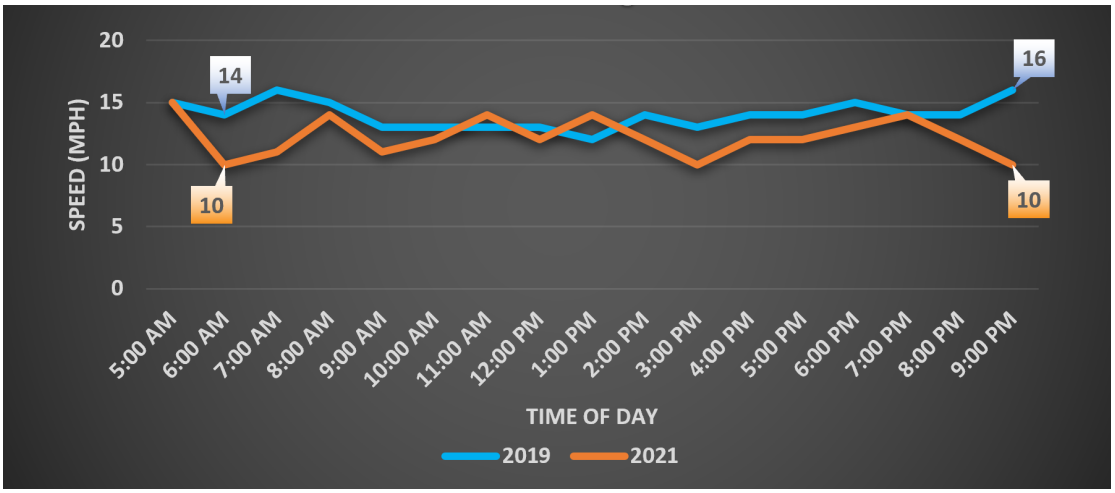

Figure 11. Mean speed for time of day along the road segment near Logan Pass for 2019 and 2021. (Source of Data: SLI)

There were generally slower speeds along this segment for the 2021 season, suggesting more congestion after the implementation of the TES. At 6 AM and 9 PM specifically, there was a more significant difference in speed. This is likely due to popular arrival times at the Logan Pass Visitor Center parking lot. During the Park's peak hours, however, speed was similar in 2019 and 2021.

As shown in *Table 6*, we observed that 2021 had a greater range of congestion percentage along the road than in 2019. In 2021, the range of congestion percentage along the sections of the road was 48%, while in 2019 it was 35%. Even though some segments of GTSR had significantly higher congestion percentages in 2021, areas that were normally more congested in past years saw a decrease in congestion level. Conversations with park staff confirmed this: Transit Fellow Ma'ayan Dembo observed that the GTSR "hot spots" were still very congested in 2021, but there were secondary areas that were less congested than previous years (M. Dembo, personal communication, September 22, 2021).

Table 6. Maximum, average, minimum, and range of congestion along the GTSR from 2017-2021. Red indicates the highest congestion per statistic, green indicates the lowest congestion per statistic. (Source of Data: SLI)

Year	2017	2018	2019	2021
Maximum	57.86%	52.38%	49.26%	56.11%
Average	33.62%	30.98%	29.04%	28.53%
Minimum	14.25%	13.45%	14.17%	8.28%
Range	43.61%	38.93%	35.09%	47.83%

While investigating this further, we found that **in 2021, non-stop trips from the West Entrance to Logan Pass, on average, took less time than in 2019.** *Table 7* displays the distribution of time that vehicles took to get from the West Entrance to Logan Pass for 2019 and 2021 between 10 AM and 4 PM. We chose these hours because they are the Park's peak hours.

As shown in the table, approximately 50% of vehicles took 60-70 minutes to arrive at the Logan Pass Visitor Center parking lot in 2021, compared to around 20% in 2019. Also, about 15% of vehicles in 2021 took non-stop trips to Logan Pass that lasted longer than 90 minutes, compared to around 33% in 2019. Therefore, we can conclude that the segments of the road leading up to Logan Pass were less congested between 10am and 4pm since a greater percentage of vehicles in 2021 were able to make quicker non-stop trips to Logan Pass.

Table 7. Distribution of non-stop trip times from the West Entrance to Logan Pass for 2019 and 2021 during the time period of 10 AM to 4 PM. Trip Count of approximately 11,000 (2019) and approximately 7,000 (2021) (Source of Data: SLI)

Non-stop Trip Duration (minutes)	Percentage of Vehicles Arriving to Logan Pass	
	2019	2021
50-60	2.54%	1.02%
60-70	**19.73%**	**50.89%**
70-80	28.18%	21.55%
80-90	16.88%	11.76%
90+	**32.67%**	**14.78%**
Total Recorded Vehicle Volume	6937	3619

Recommendation: Continue the TES for the GTSR in 2022

While we found that some areas of the GTSR were more congested in 2021 than in previous years, the average congestion of the road decreased. Since the 2021 TES was effective in reducing overall volume and congestion along GTSR, we recommend that GLAC continues the system for the 2022 season.

Impact of TES on Valley Entrances

Valley entrances of GLAC (Many Glacier, North Fork, and Two Medicine) have long been visited by area residents and backcountry hikers for their low-visitation numbers and solitude. These areas provide limited staffing and parking for visitors. Parking is known to become occupied at early hours of the day (James Dahlstrom, personal communication, September 27, 2021; Brian Drew, personal communication, September 27, 2021). **The 2021 TES created visitation demands in GLAC's valley entrances which were not sustainable for the Park's staff or infrastructure, resulting in frequent closures and reduced ranger availability.**

From 2019 to 2021, IRMA shows that throughout June, July, and August of 2021, there was a 33.5% increase in vehicles at Two Medicine, a 6.5% increase in Many Glacier, and a 19.9% increase at North Fork compared to 2019. Walton Two Medicine District Ranger Brian Drew and North Fork District Ranger James Dahlstrom explained that demands for park entrances were so high in 2021 that entrance gates had to be closed regularly throughout the 2021 season (James Dahlstrom, personal communication, September 27, 2021; Brian Drew, personal communication, September 27, 2021). This required rangers to be on site at the gates to turn visitors away and confront them about reopening times, which involved much more labor than those districts had available. When asked if this was overwhelming for park staff, Dahlstrom responded with "every day," while Drew described the situation as "frustrating." Drew also noted that many ranger responsibilities were "neglected" from the need to control parking (J. Dahlstrom, personal communication, September 27, 2021; B. Drew, personal communication, September 27, 2021). Even Many Glacier – which was under construction for most of the 2021 season – experienced an increase in vehicles from 2019. Chief Mountain District Ranger Dave Smith described the combination of construction, congestion, and upset visitors as "unmanageable" for staff. (D. Smith, Personal Communication, September 27, 2021).

Recommendation: Implement a TES in 2022 for Two Medicine, North Fork, and Many Glacier

If the TES is to continue in the 2022 season, our evidence suggests that visitors without entry tickets will again flock to the valleys. With no means to control visitors other than closing gates, the valleys will experience the same overcrowding that they did in the 2021 season. In order to curb the increase in visitation in the valley areas and ease strain on park staff, we recommend that park administration investigates the feasibility of a TES for Two Medicine, North Fork, and Many Glacier. Dahlstrom expressed concerns about having a TES for North Fork, saying it will take away from the traditional, spontaneous nature of travel in the valley. Additionally, staff would still need to turn visitors around at the gates if they showed up without tickets, so there's no evidence that this would reduce valley entrance gate congestion, or that it would reduce strain on staff in those areas. Despite these concerns, all four park rangers that we spoke to, Dahlstrom included, agreed that the Park should at least consider a TES for the valleys if the GTSR TES is to continue in 2022.

Impact of TES on Travel to Surrounding Communities

Our sponsors expressed an interest in learning where visitors go after being turned around at the West Entrance Ticket Corral. **Except for the visitors that ended their trips in West Glacier, most visitors went to Columbia Falls, Kalispell, Whitefish, and Hungry Horse while fewer visitors went to Coram, Martin City, and Lakeside.**

Approximately 72% of turned-away visitors ended their trips in West Glacier. This indicates that they stopped for more than 5 minutes there; this could be due to visitors stopping to decide where to travel next or to visit the offerings in West Glacier. To look more into the distribution of visitor travel to other communities, we re-ran the analysis without including West Glacier as a destination. *Figure 12* shows the distribution of communities that visitors went to after being turned-away.

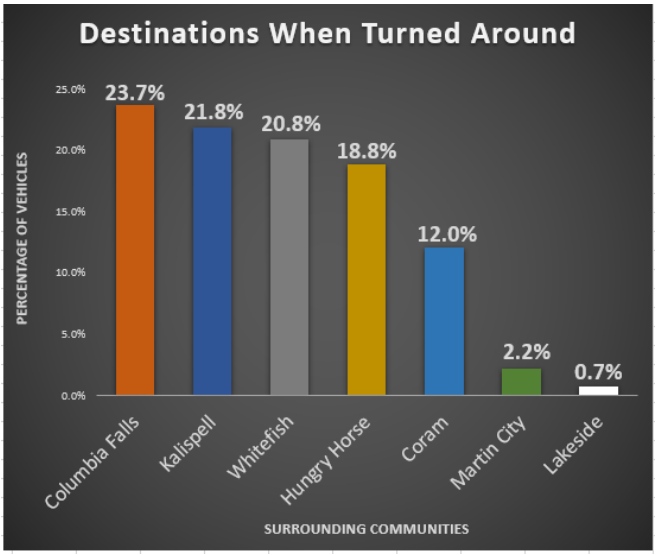

Figure 12. Destinations of vehicles after being turned around in the Ticket Corral, excluding West Glacier. Trip count of approximately 700. (Source of Data: SLI)

Future Research: Conduct In-Depth Surrounding Communities Analysis

Our project was somewhat limited in its ability to gain insightful data about surrounding communities. For example, the data we received may have been skewed by the presence of COVID-19 and visitors' unwillingness to visit more populated communities. COVID-19 also limited our ability to conduct qualitative research on visitor traffic patterns through interviews with business owners in surrounding communities (hotels, restaurants, and entertainment attractions). We were able to get quantitative data through SLI but had no ground-truth data with which to verify these findings. If GLAC continues with a TES in coming years, we recommend conducting a study on the impacts of the TES in surrounding communities with a focus on interviewing local business owners.

Impact on Overall Visitor Experience

We were only able to gather second-hand data from park ranger interviews and draw conclusions on the visitor experience from these interviews and our congestion analyses. From this, we concluded that the TES had positive and negative impacts on the overall visitor experience. **The TES improved the visitor experience for those who were able to purchase a GTSR ticket, but many visitors who were unable to purchase a ticket were frustrated with the lack of accessibility to the Park.** Visitors unable to purchase tickets faced many complications beyond not being able to enter the GTSR.

Through speaking with park rangers on their observations of the visitor experience in 2021 compared to 2019, we gathered that there were mixed results depending on the user group. Ranger Operations Coordinator Micah Alley expressed that those who were able to reserve entry tickets for the GTSR thought their visit was "not as congested" and "a lot nicer than it was in previous years" (M. Alley, personal communication, September 23, 2021). This, supported by our SLI GTSR congestion analysis, shows that **the decreased congestion along the GTSR due to the TES had a positive impact on the visitors who were able to enter the GTSR.** However, not every visitor had a positive experience at the Park in 2021.

Nearly 19% of visitors who arrived at the West Entrance were turned away. Micah Alley attested to this user group generally being "really frustrated" (M. Alley, personal communication, September 23, 2021). He also noted that **many of the visitors who arrived at the entrance did not know that an entry ticket was required.** This was particularly true for elderly visitors, whom Dahlstrom described as "harder to reach" given a common lack of internet access, meaning they had no awareness of the TES or a way to purchase a ticket (J. Dahlstrom, personal communication, September 27, 2021).

Many of the visitors that were turned away were redirected by park rangers to North Fork and Two Medicine. North Fork, which only has a capacity for 120 vehicles and is typically used for backpacking trips, had an influx of these turned-away visitors to the parking lot. James Dahlstrom, North Fork District Ranger, personally attested to an influx of unprepared visitors who were turned away from the GTSR. Similarly, in Two Medicine, Brian Drew attested to this "new group of visitors...need[ing] a lot of help" (B. Drew, personal communication, September 28th, 2021). Rangers in Two Medicine were often asked what to do, as there are only roads to the lake and trailheads. Both areas proved not to be very accessible for visitors who were initially intending to visit the GTSR, which diminished their visitor experience. However, some of the visitors were unable to enter any part of the Park at all.

With visitation in the valleys of the Park drastically increasing, the group of visitors who were directed to North Fork, Two Medicine, or Many Glacier were often met with yet another closed gate after enduring a multiple hour drive. For these visitors, Brian Drew conveyed that "their visitor experience was not great," and James Dahlstrom, described them as "angry and upset." (B. Drew, Personal Communication, September 27, 2021; J, Dahlstrom, Personal Communication, September 27, 2021). **Those who were told to relocate to a congested area of the Park after being rejected from entering the GTSR had a diminished visitor experience as compared to visitors from previous years.** This increased visitation to the

valleys and the requirement of a ticket to enter the GTSR corridor also changed area residents' experiences in the Park.

The 2021 TES decreased area residents' visits to the Park. Several park rangers expressed that, through their personal interactions with visitors over the 2021 season as compared to previous seasons, area residents' visitations to the Park had decreased (B. Drew, Personal Communication, September 27, 2021; J, Dahlstrom, Personal Communication, September 27, 2021). This was of particular concern in North Fork and Two Medicine. These locations are now overwhelmed by the group of visitors who had originally planned to drive the GTSR. To corroborate this, we analyzed the home locations of all visitors to the Park, gathering over 300,000 trips. As shown in *Table 8*, we analyzed the 500 most popular visitor home locations in 2019 and 2021 and found that significantly fewer Montana residents visited the Park during the peak season in 2021.

Table 8. Home locations of visitors to GLAC in 2019 and 2021 (Source of Data: SLI)

State	2019	State	2021
MT	26.70%	MT	13.93%
CA	2.77%	CA	9.73%
MN	2.54%	MN	5.90%
WI	2.30%	TX	5.53%
IL	2.04%	WA	4.15%
WA	1.96%	WI	3.93%
FL	1.40%	IL	3.63%
MI	1.13%	MI	3.49%
TX	1.04%	NY	3.09%
GA	0.92%	TN	3.03%

Recommendation: Improve Public Awareness and Understanding of the TES

To reduce the 19% of visitors being turned away from the West Entrance and the exclusion of elderly visitors, we recommend that the Park improve publicity and understanding of the system in Fall 2021 rather than waiting until Spring 2022. James Dahlstrom suggested that, if the Park were to continue the GTSR TES for 2022, GLAC should inform local hotels and attractions about the system (J. Dahlstrom, Personal Communication, September 27, 2021). With more public awareness, visitors will be able to better plan their trip and understand the process of ticketed entry in the Park. This would theoretically lead to less turnarounds so that GLAC could improve visitor experiences and station fewer staff at the West Entrance. More public awareness across different online and in-person platforms would also be likely to reach elderly visitors, enabling them to plan an online ticket purchase beforehand.

Recommendation: Investigate an Annual Park Pass for Area Residents

To reduce the exclusion of area residents to the Park, we recommend that GLAC investigate the practicality of an annual park entry ticket for area residents. This would ensure that area residents have access to the GTSR and valley entrances, which had been part of their lifestyle before the 2021 TES. However, an annual ticket would result in less ticket accessibility for non-area residents if there were to be an equivalent number of entry tickets available in future seasons. Therefore, an annual ticket for area residents would exclude non-area residents from the Park, with no guarantees that area residents would use their ticket predictably. This could result in the Park not accommodating as many visitors on average as it had during the 2021 TES, and requires the Park to decide between different user groups.

Recommendation: Conduct In-Depth Analysis of the Impacts of the TES on Visitor Experience

Due to not being on-site in the Park during the 2021 TES, we had no opportunities to interview any visitors. Our perception of the visitors' experiences came exclusively from second-hand park ranger experiences and our assumption that lower congestion would cause an improved visitor experience. Because of this, we recommend further analysis with interviews and surveys of Park visitors on their experiences both in the GTSR corridor and the valleys. This would make any differences in the visitor experience before and after the implementation of the TES more observable, and ultimately allow the Park to further evaluate the TES on this criterion.

Additional Research Recommendations

With the first year of the TES completed, there is a significant amount of research needed to further evaluate and improve the system. If GLAC continues with a TES in 2022, **a similar in-depth analysis should be completed comparing any differences in the two years of the system with the years prior**. With this evaluation, there should be a focus on any differences GLAC administration makes to the 2022 TES. This will help the Park continue to improve the TES for future years.

Additionally, we recommend that future research groups working in national parks **evaluate Streetlight Insight as a visitor mobility analysis tool.** Throughout the project, we noticed several benefits to using a big data platform, but with it came many limitations. In the context of evaluating GLAC's 2021 TES, we were able to compile thousands of trips to track entrance and exit times of the Park. We were also able to access average speed and congestion data for the GTSR.

However, Streetlight Volume is an approximation of the number of trips based on ground-truth data and is not comparable to car counter data. Trying to track trips ending in smaller parking lots and turn-off areas on the road did not provide a sufficient volume of data, and SLI rejected smaller zones due to anonymization concerns. This was also the case when we attempted to examine pedestrian data on GLAC trails, so we were unable to confirm the volume accuracy of pedestrian activity. Additionally, since SLI does not track trips that stop for 5 minutes and continue again, analyzing a vehicle's second destination was not possible.

For these reasons, we recommend an evaluation of SLI as a visitor mobility analysis tool for use in national parks. In this, research groups should compare how accurate and useful the data is compared to car counters, trail counters, and hand-recorded data.

Conclusions

We began this project by identifying key areas of congestion which we could comparatively analyze with a big mobility data platform, Streetlight Data. We interviewed park staff who corroborated data, and provided additional insight on their personal experiences with the TES. From this, we were able to draw conclusions impacts of the TES. Additionally, we proceeded to make recommendations to park administration and for further research on how to improve the system and further achieve the Park's goals.

We could not make one singular evaluation of the TES as it would not capture the entirety of the impacts on different areas of the Park. For this reason, we needed to evaluate the successes, limitations, and unintended consequences of the TES in each area of the Park and on the overall visitor experience.

The West Entrance experienced a lightened and more temporally redistributed load of vehicles throughout the day. With this, however, the peak vehicle loads before and after the TES enforcement times caused congestion and put a heightened strain on the park staff.

The GTSR saw lower average congestion throughout the TES as compared to previous years, most notably demonstrated by the reduced time it took visitors to get to Logan Pass Visitor Center parking lot during peak hours. There were still, however, different areas of the road that remained congested.

Two Medicine, Many Glacier, and North Fork saw an increase in visitation after the implementation of the TES. Often exceeding capacity, these areas faced unprepared visitors and had to close regularly.

The TES did improve the visitor experience of those who successfully purchased an entry ticket. Those who could not purchase a ticket or wished to seek isolation in the valleys, however, had a more negative visitor experience.

Ultimately, GLAC implemented the TES in order to reduce traffic backing up outside the Park, reduce congestion along the GTSR, and provide entrance certainty for visitors. Facing increasing visitation trends and an ongoing pandemic in its pilot year, the TES accommodated the Park administration's initial goals, albeit with several unintended consequences.

The goal of the National Park Service is inherently a compromise: to connect people to parks while preserving the natural environment for future generations. Glacier National Park's 2021 Ticketed Entry System was an important pilot program that allowed visitors to enjoy the Park in controlled moderation while preserving both the visitor experience and the natural environment.

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Chief Mountain Ranger, Dave Smith

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