Evaluating Glacier National Park's 2021 Ticketed Entry System: Supplemental Materials

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Appendix A: Methods to Mitigate Congestion

Large parks and tourist attractions control influxes of visitors by using similar strategies to mitigate congestion and communicate conditions of congestion to visitors. These strategies – including signage, ticketing, shuttle services, use of social media, expansion of infrastructure, and reservation systems – are initially proposed through park management plans, such as the GTSR Management Plan established for GLAC in 2019. The implementation of these strategies is determined by certain indicators, such as vehicles observed at one time (VAOT) and volume of hikers per day on trails (National Park Service, 2019). Once specific thresholds (often defined in the management plan) for these indicators are exceeded, mitigation strategies can be implemented in different areas to bring those thresholds back within an acceptable range. Indicators and thresholds for visitor use are currently monitored on-site by park staff (National Park Service, 2019).

Signage

Both the NPS and large theme parks employ various forms of signs, notices, and cones along popular roadways to manage vehicle and visitor congestion in parks (Milman et al., 2020). These methods warn travelers of high vehicle congestion based on VAOT and persons observed at one time to discourage them from entering certain sections of the park (National Park Service, 2019). In addition, park staff block off road shoulders and other areas with cones as an effort to prevent parking in prohibited areas (Barrameda et al., 2018).

Ticketing

The NPS is responsible for issuing parking tickets to visitors who park outside of designated areas, and therefore contribute to vehicle congestion along roads and parking lots. While the NPS normally tries to avoid ticketing visitors, they still do so as an attempt to minimize illegal parking and maintain certain congestion thresholds based on VAOT (National Park Service, 2019). These efforts can prove to be unsuccessful as the NPS has no concrete way to enforce signage or tow vehicles on a large-scale, and many people don't mind paying the price of parking tickets in exchange for a day in a national park (Murray, 2019).

Shuttle Services

Shuttle systems have been an effective way to transport visitors around national parks and theme parks while simultaneously reducing the amount of vehicle congestion on the roads (Milman et al., 2020). However, when visitation spikes, shuttle services become overwhelmed, resulting in long lines and waiting times for transportation. Many shuttle services, including GLAC's, are not large enough to meaningfully reduce the effects of congestion, and the frequent stops these shuttles make can also add to vehicle traffic (Barrameda et al., 2018).

Social Media to Communicate Congestion

The NPS and many large theme parks have taken to Facebook and Twitter to promote alternate forms of transportation in the park as well as provide visitors with information involving closures and wait times (Milman et al., 2020). Because of the lack of cell service in national parks, real time updates on social media are not available to visitors on the inside but can reach those outside the park to discourage further congestion.

Expansion of Infrastructure

Large parks can also mitigate vehicle and pedestrian congestion by expanding the physical infrastructure of the park. GLAC's 2019 GTSR Management Plan, for example, proposes strategies including the installation of bicycle racks to promote alternate transportation and decrease vehicle presence, as well as the construction and expansion of roads, trails, and parking lots to increase their carrying capacities (National Park Service, 2019). While expanding infrastructure would allow for greater dispersion of vehicle and pedestrian congestion, it would involve destroying parts of the environment that GLAC serves to protect (National Park Service, 2019). Because of this, it may not be an optimal mitigation strategy for the NPS.

Reservation Systems

Reservation systems allow parks and tourist attractions to ensure roads, trails, and parking lots do not exceed carrying capacities by requiring visitors to purchase access to those areas before arrival. Primary examples include the introduction Glacier National Park's Ticketed Entry System (TES), active May 28th, 2021, through September 6th, 2021, and the re-introduction of a reservation system for Yosemite National Park (YNP) active April 21st, 2021, through September 30th, 2021. These reservation systems are meant to control the number of vehicles entering the parks and reduce overall VAOT on roads and in parking lots, as well as hiker volumes per day on trails. Reservations are necessary to enter the GTSR from both the West and Saint Mary entrances, and to enter any section of YNP (National Park Service, 2021). These reservation systems require visitors to set up an account on www.Recreation.gov and pay a $2 transaction fee (Glacier & Us, 2021). In GLAC, around ¾ of reservation tickets are released 60 days in advance, while the remaining ¼ of tickets are released 2 days in advance. In YNP, reservations for May and June, July, August, and September become available on April 21st, April 28th, May 5th and May 12th respectively, while a limited number of passes are released 7 days in advance (National Park Service, 2021). GLAC limits the number of entry tickets to 4,600 vehicles per day, however, parking along the GTSR only offers 2,100 parking spots (Peterson, 2021). In the summer of 2020, YNP reportedly allowed up to 11,000 reservations per day, which is said to increase by up to 1,850 during the summer of 2021. Tickets are valid for 7 days and 3 days in GLAC and YNP respectively. Reservations will not be needed in either park for those who choose to hike or bike the roads, offering an incentive for visitors to use alternative transportation (National Park Service, 2021). *Table S1* provides a comparison of the different aspects of each mitigation strategy.

Table S1: Comparison of Mitigation Strategies

Aspects / Strategy	Frequency of Use	Success at Mitigation	Cost of Implementation	Cons of Strategy	Feasibility	Mitigated Congestion Variables
Signage	High	Successful when properly observed	Overhead cost of signage	Signs/cones could be missed or ignored	Easy for staff to implement	-VAOT -Persons observed at one time
Traffic Violation Tickets	High	Not very successful as ticketed vehicles have already contributed to illegal congestion	Cost of ticketing materials and labor	Ticket costs don't always deter illegal parking	Easy for staff to implement	-VAOT in undesignated areas
Shuttle Services	High	Very successful at reducing VAOT	Cost of vehicles, gasoline, maintenance, and labor	Many visitors may choose to drive personal vehicles	Easy to implement besides ongoing costs	-VAOT
Social Media	High	Success not known	No known cost	Visitors must check social media platforms	Easy for staff to implement	-VAOT -Persons observed at one time
Expansion of Infrastructure	Low	Low-High success depending on size and type of infrastructure	Large overhead cost of construction	Construction degrades Park environments	Not easily implemented. Requires costly projects and disruptive construction	-Carrying Capacities
Reservation Systems	Moderate – typical during peak seasons	To be determined	Cost of online reservation system development	The Park could lose profit by limiting visitors	Easy for park staff to implement once the system is set up	-VAOT -Persons observed at one time

Appendix B: Methods to Analyze/Visualize Congestion

Statistical Analysis

Statistics are useful in simplifying a large amount of data. Means, or averages are effective in displaying the middle point of a dataset. In a study analyzing mobility data of cruise ship passengers, the average distance of tourists from the port was determined in order to analyze their travel patterns (Ferrante, 2016). Medians are more accurate in cases where the mean can be impacted by extreme outliers (Wheelan, 2013).

Statistical tests can also be used to verify the significance of collected data. For a statistical test, the resulting *p*-value indicates significant results if it is generally less than .01 (or whatever is the established significance level). A statistical test was used to determine whether the clustering of tourists in Seoraksan National Park was significant during certain seasons (Kim et. Al, 2018). *Figure S1* includes the p-value for this test for each season, as well as the observed and expected median distance between tourists in the park. Understanding these statistics is helpful to gain a better understanding of visitor mobility.

Season	Observed MD	Expected MD	NNR	*p*-Value	Clustered
Spring (March–May)	36.78	320.05	0.11	<0.01	Yes
Summer (June–August)	36.21	238.50	0.15	<0.01	Yes
Fall (September–November)	33.74	204.30	0.16	<0.01	Yes
Winter (December–February)	51.92	344.32	0.15	<0.01	Yes

Note. MD: Medan distance; NNR: Nearest neighbor ratio.

Figure S1. Median distance, nearest neighbor ratio, and p-value representing significant congestion in Seoraksan National Park through different seasons (Kim et. Al, 2018).

Charts/Graphs

The representation of data points in a chart or a graph can easily turn any dataset from a series of numbers to visual representation from which trends and correlations can be interpreted. Graphs and charts become increasingly useful when working with larger datasets, as they condense copious amounts of data points to communicate key information easily and effectively (Slutsky, 2014). Charts and graphs can be effective in showing patterns in mobility data over time. For example, *Figure S2* portrays the number of visitors at Freycinet National Park sites in Australia over the first few months of 2016 (Hardy, 2020).

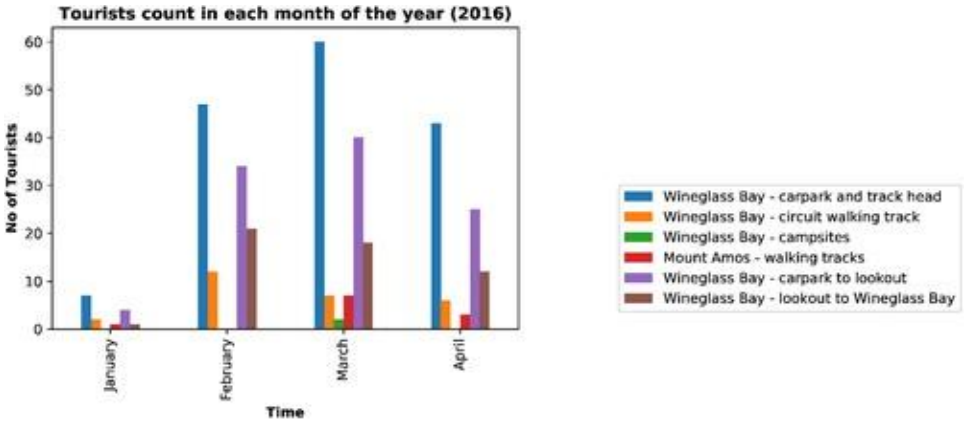

Figure S2. Number of Tourists in Six Different Freycinet National Park Sites over the First Few Months of 2016 (Hardy, 2020).

Graphs such as these are helpful in determining peaks and/or valleys in mobility. Pie charts and bar charts can be effective in displaying the distribution of visitor demographics.

Heatmaps

Heatmaps are data visualization techniques that show volumetric spatio-temporal data with the use of shades of colors over a given time or area (Birkett, 2019). To better understand mobility analysis within a city, a study was done by the Institute of Electrical and Electronics Engineers. This study took geospatial traffic data in an urban area and compiled the data into several heatmaps (Senaratne et al., 2018). Heatmaps can clearly compile thousands of mobility data points into easily understood visual representations, in this case, of the most popular traffic patterns within this urban setting. This same concept, however, can be applied to any location in which enough mobility data is collected to be able to display an accurate visualization of traffic patterns. The University of Montana used a similar visualization to portray the number of visitors on different trails in GLAC (shown in *Figure S3*). Red trails indicate very high use, while green trials indicate low use.

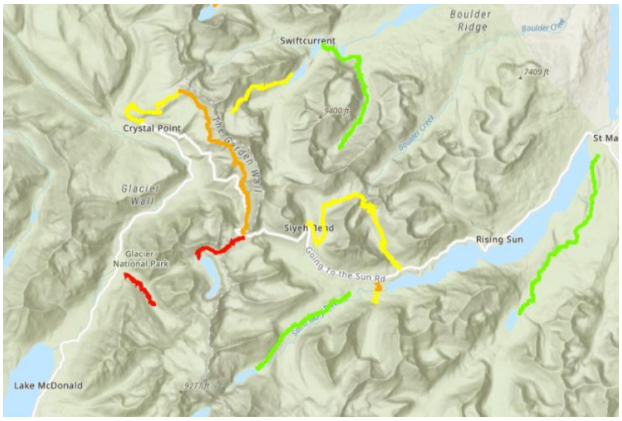

Figure S3. Different Trails in Glacier National Park, Labeled by Amount of Traffic (University of Montana, n.d.)

Appendix C: Data Bias

Data bias involves the skewing or inaccuracy of data due to errors in data collection or inaccurate sampling (Lim, 2020). When collecting and analyzing datasets, data bias can often become an issue. Big mobility data is often collected by correlating LBS throughout various times of the day and year with zonal census data. This leads to generally accurate interpretations of personal qualities of data collected. However, this can also cause inaccurate assumptions, specifically related to race, education, and income levels due to inaccuracies with generalizations for community zones. For example, collecting GPS data through phone apps will exclude visitors who may not have a phone. This must be kept into consideration when making conclusions based on the collected data.

Appendix D: Interview Questions

Preamble for Informed Consent

> *We are a group of students from Worcester Polytechnic Institute in Massachusetts, and we are working with Glacier National Park in Montana, U.S.*
>
> *We are conducting a survey of Park staff to learn more about how the 2021 Ticketed Entry System in Glacier National Park may have affected visitor experience, traffic volumes, and overall flow of traffic in and around the Park. We believe this research will ultimately help us to make suggestions which can mitigate the effects of high traffic and pedestrian congestion, as well as increase visitor experience in the Park.*
>
> *Your participation in this survey/interview is completely voluntary and you may withdraw at any time. With your permission, your name, position, and information that you provide us may be quoted in our written results. The inclusion of this information is completely voluntary, and you may ask that it does not appear in the written report. Any quoted information included in the results would be emailed to you in context so you may approve of it before it is released.*
>
> *Your participation is greatly appreciated. If you have additional questions, you may reach out to our faculty advisors (Frederick Bianchi: bianchi@wpi.edu; Corey Dehner: cdehner@wpi.edu; Seth Tuler: stuler@wpi.edu). If you would like, we are happy to share a copy of our results at the conclusion of the study.*

Questions for Richard Kern (Acadia National Park Visitor Mobility Analysis Project)

General Streetlight Questions:

- What was the most challenging part of using Streetlight?
- Were there any use cases where Streetlight was not effective? Was it not able to access the correct data, or did you have trouble running an analysis that would acquire the needed data?
- Were there any cases where you had to adapt the information you wanted to be more in line with what Streetlight could provide?
- What were some cases where Streetlight was really effective?

Technical Streetlight Questions:

- What types of analyses did you run most often?
- Did you run any analyses on trails, and, if so, how effective were they? Were you able to find enough volume passing through trails?
- A lack of cellular connection shouldn't interrupt LBS data points, but did you find any issues with "dead zones" when looking through data? Any areas where you were concerned about the accuracy of the data, either for this reason or another?
- Did you ever run any analyses that were put into Manual Review, and, if so, what caused this? How did you resolve the analysis so that it could run?
- This will likely be covered in your reports, but did you run tests to validate Streetlight data, particularly the Streetlight Volume data? If so, how accurate was Streetlight for roads? Parking lots? Trails (if applicable)?

- If we don't have the means to validate the results in the same way that you did, do you have any suggestions for acquiring meaningful data? Should we be able to draw meaningful conclusions from Streetlight Index and Streetlight Calibrate Index data?
- How often did you export data from Streetlight? And in what situations did you need to run your own post analysis on the data?
- Do you have any suggestions for the best way to externally parse data (Excel, Access, Tableau, other database or visualization software)?

Project Management Questions

- Were there any analyses that you wanted to run but ran out of time to complete?
- Approximately how many analyses were you able to run per week?
- How did your ability to run analyses change as you got more comfortable with the software (how steep was the learning curve)?
- What was your division of work like (how many people focused on Streetlight vs. other tasks) and would you recommend something similar? Did this work well? Anything that you might change?

Concluding Questions

- Looking back, is there anything you wish you had known about SLD when first starting the project?
- Are there any additional concerns that we may not be anticipating as we start our project?

Questions for Transit Fellow Ma'ayan Dembo

Ticket System Questions

- Can you tell us about the process that led to the implementation of the TES?

Data Acquisition Questions

- You're using car counters to record data. Is the West Entrance car counter located past both Apgar and Lake MaDonald? If not, where is it?

Quantitative Data Corroboration Questions

- Do you have a record of the construction on GTSR? Were there any projects that would affect our data (2021, 2019, 2017)?
    - We were seeing a slower speed around Logan Pass and were wondering why this might be?
- How did you turn people away in 2019 when the West Gate closed? Was it a similar procedure to the TES? (NOTE: In case we want to do a surrounding communities analysis from 2019)
- How did you turn people away at the East Entrance (2021 and other)? Were some people allowed in without a ticket?

  Streetlight Corroboration/Follow-up Questions
- We noticed a difference in West Entrance times pre and post reservation (spikes at 6am and 5pm). Is this consistent with your observations?
- What was the process for a visitor entering at the West gate? Our data shows a slower speed through the gate than in previous years, and we were wondering if having to present two tickets slowed down entry?

- From 2019 to 2021, we noticed different peak activity times in the Logan Pass Visitor Center Parking Lot. Does this strike you as typical? Are these times relatively predictable?
- We noticed that people are leaving the Park later in 2021 than in 2019. Does this align with what you observed? Do you have any ideas as to why this might have occurred?
- We noticed an increase in congestion along the GTSR just before Logan Pass Visitor Center, by Jackson Glacier Overlook, and in between Logan Creek Bridge and Big Bend. Does this align with your observations?

Questions for Park Rangers

These questions were presented to Ranger Operations Coordinator Micah Alley, Walton Two Medicine District Ranger Brian Drew, North Fork District Ranger James Dahlstrom, and Chief District Mountain Ranger David Smith:

- How long have you worked in GLAC (greater than or less than 3 years)?
- Do you work/live in the area year-round, or just for the summer season?
- We are trying to assess the impacts of the 2021 TES on visitor patterns. Did you notice any shifts in visitor or traffic patterns this year as opposed to 2019? Some things we are particularly interested in:
  - Did you notice a change in what times the parking lots in your area typically fill up?
  - Was there a change in the turnover rates in parking lots in your area?
  - Was there a change in which trails visitors typically hiked?
- Were there noticeable changes in visitor attitudes towards trail congestion and availability of parking?
- What changes in visitor behaviors could have also been impacted by the pandemic (as opposed to just the TES)
- Did you notice a change in visitors from local communities vs. visitors from farther away? If so, why do you think this was?
- Did any of your staff express feeling overwhelmed during the TES? Did you, yourself, feel overwhelmed during the peak season?
- Do you believe that the valleys (North Fork, Many Glacier, and Two Medicine) would benefit from a TES if the GTSR TES is to continue next season?

Appendix E: Streetlight Analysis

Analysis Overview

Table S2. Streetlight Insight Analysis Overviews

Analysis Type	Available Output
Zone Activity: useful for gaging general travel activity in an area and exploring demographics of travelers	Streetlight Vehicle Volume Trip Attributes Traveler Attributes Home/Work Locations
Origin-Destination: Useful for looking at where travelers are going, what times they arrive at specific areas	Streetlight Vehicle Volume Trip Attributes Traveler Attributes
Segment Analysis: Useful for looking at the distribution of congestion/speed along different segments of a road	Speed of trips Duration of trips Congestion factor

West Entrance and Ticket Corral Activity

To evaluate the times vehicles entered the GTSR through the West Entrance and the Ticket Corral, we used a zone set of two zones for 2019 and 2021. *Figure S4* shows the zone set used to collect vehicle entrance times. To collect data on overall park entrance times, we used all times. To collect data on corral entries during the TES hours, our analysis included only vehicle entries from 6 AM to 5 PM. All analyses used all days of the week.

Figure S4. Zones are used for the entrance times to the park as well as Corral entrances. The polygon zone in green represents the Corral, while the zone in red is a passthrough destination zone which captures vehicle trips that move through the West Entrance. This analysis captured 5000 trips (for 2021) and 7000 trips (for 2019).

West Entrance Exit Times

To collect data on the times visitors exited the park, we set the West Entrance as the origin and used SLD's preset locations in the surrounding communities, shown in *Figure S5*, this analysis will count all vehicles who went from the West Entrance to any of the surrounding areas (shown in green). This analysis was conducted across all times and all days.

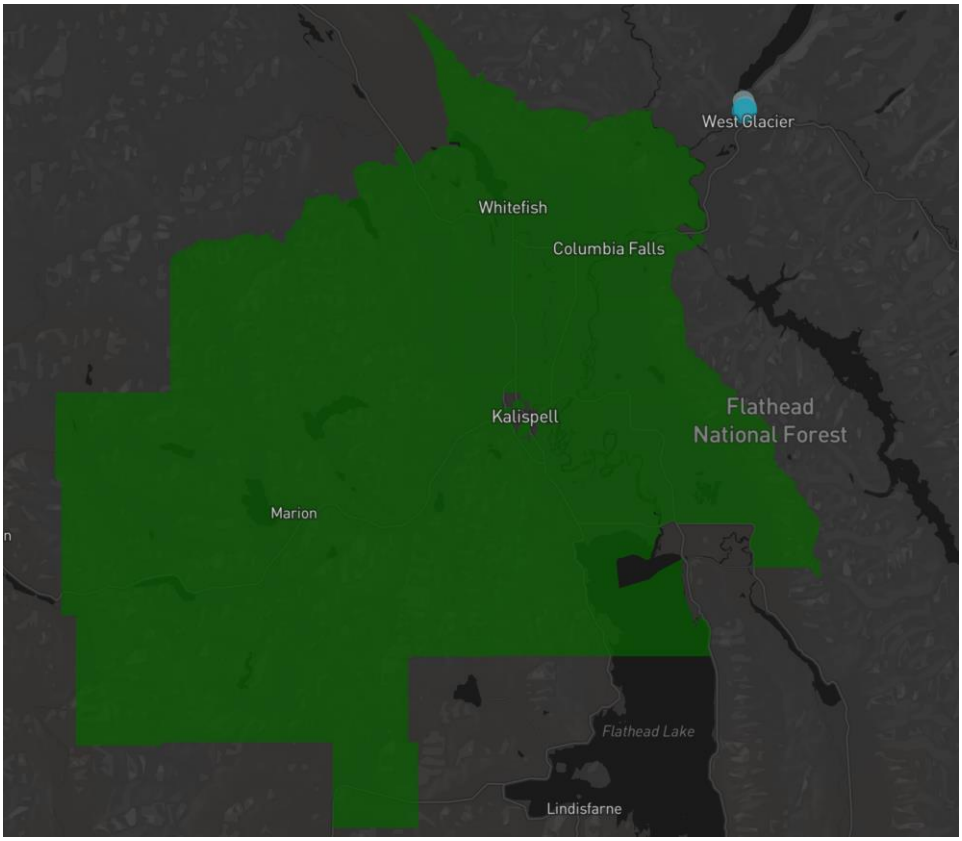

Figure S5. Zones are used for the West Entrance exit times analysis. The origin zones in blue are segment zones at the west entrance and the destination zones are census zones around the surrounding communities. This analysis captured 2000 trips (for 2021) and 3000 trips (for 2019).

GTSR Segment Analysis

To analyze congestion along GTSR, we broke the road down into 83 segments shown below in *Figure S6*. We used metrics available in Streetlight Data to compare the average volume, speed, and congestion along the road in 2017, 2018, 2019, and 2020.

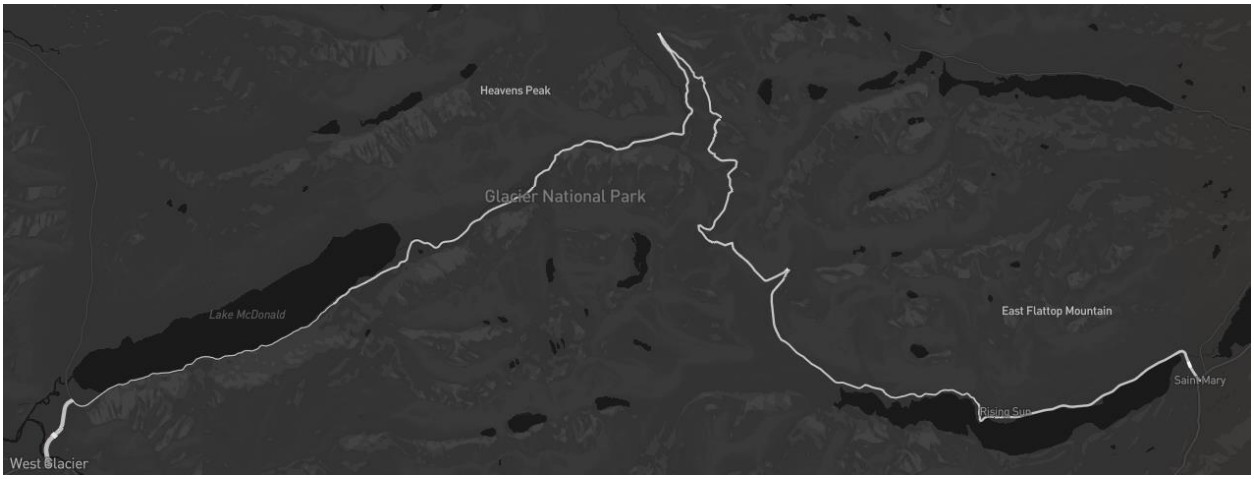

Figure S6. Combined 83 Segment Zones for the GTSR Segment Analyses. From these segments, we tracked over 75,000 vehicle trips along the road for each year.

Vehicle Volume

We looked at the estimated vehicular volume along the GTSR by mileage. The segments begin at U.S. HWY 2 and continue along the GTSR as shown in *Figure S6*. *Figure S7* is the estimated total trip count through each segment of the road. NOTE: The data from 2021 is preliminary, meaning that it has not been processed by the same algorithms as the data for other years. Thus, volume may be greater or less than it will be after it is fully processed.

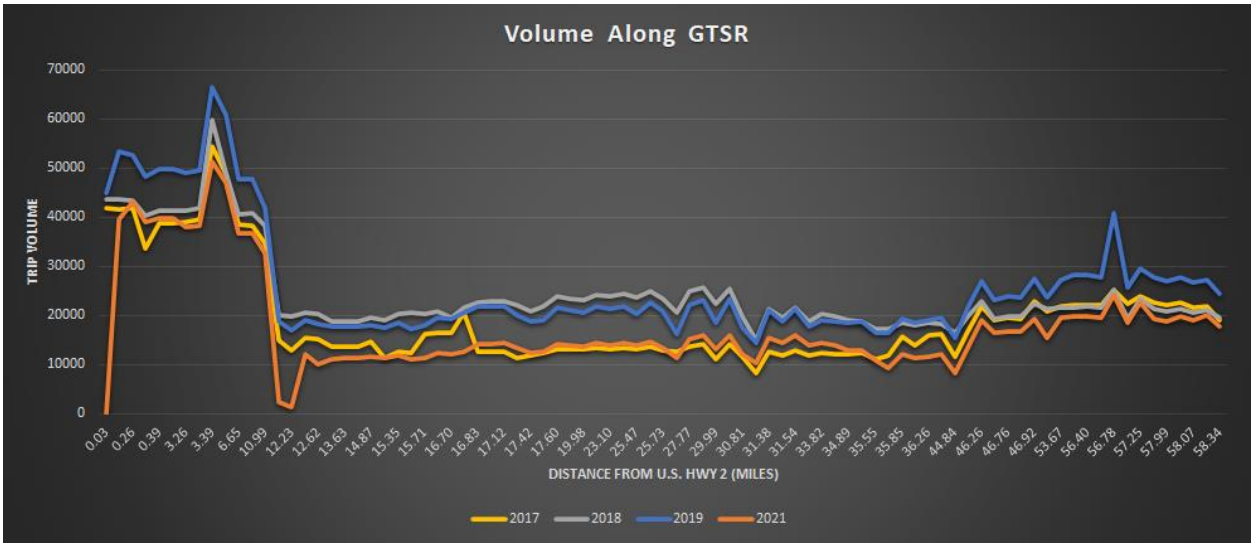

Figure S7. Estimated vehicular volume along GTSR by mileage from U.S. HWY 2

We found that the average volume along the GTSR in 2021 was lower than in previous years. This is corroborated by park data and car counters from Irma.nps.gov that indicate there was a 9.7% reduction in GTSR entrances from 2019 to 2021.

Average Speed

Using the Streetlight Insight speed metric, we looked at average speed for each segment along the GTSR for 2017, 2018, 2019, and 2021. *Figure S8* shows the average speed by mileage.

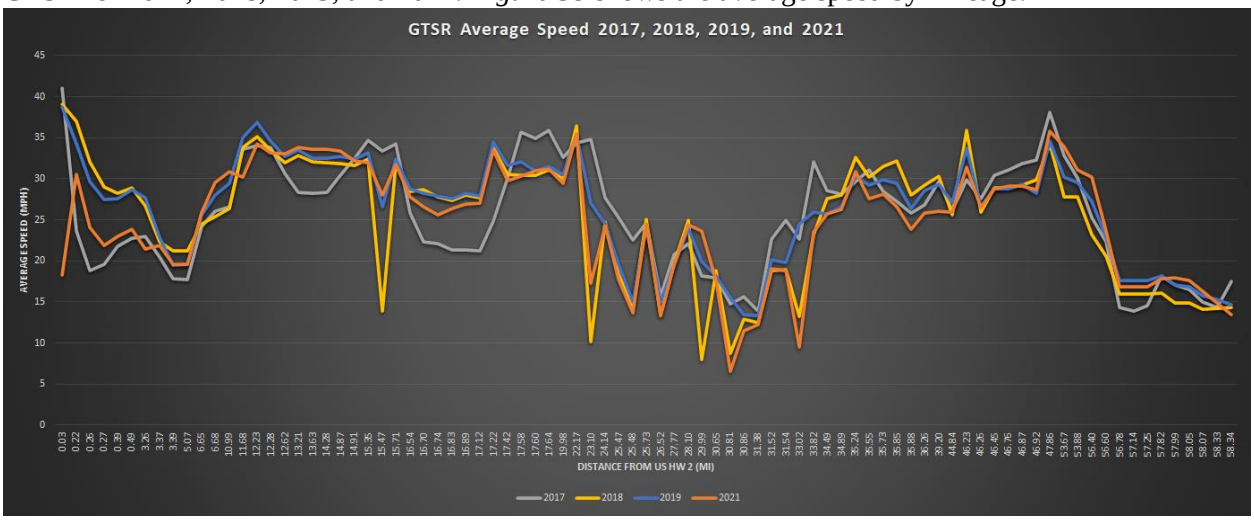

Figure S8. GTSR Average Speed by mileage from U.S. HWY 2

Average Congestion

The congestion percentage for each segment for each year is shown below in table S3. The algorithm used by SLD to measure the congestion metric is shown by the following equation:

$$Congestion\ Percentage = \left(1 - \frac{Average\ Speed}{Maximum\ Average\ Speed}\right) \cdot 100$$

Table S3 shows a detailed breakdown of the congestion percentage along each of the segments of the GTSR. *Figure S9* shows a graphical representation of the data shown in *Table S4*.

Table S3: Breakdown of the congestion percentage for each segment along the GTSR for each year. Red indicates the most congested road segment for each year.

Mileage	Streetlight Data Congestion Metric				Segment Location
	2017	2018	2019	2021	
0.038678	25.55%	27.53%	31.49%	37.44%	Highway converge
0.128373	38.18%	26.44%	30.78%	39.18%	Entrance tunnel
0.186575	47.73%	38.87%	30.41%	25.70%	Entrance segment 3
0.421148	52.29%	47.07%	30.36%	28.70%	Apgar Village Lodge
0.522824	32.21%	47.13%	30.36%	32.17%	River Bend to Flathead

Milage	2017	2018	2019	2021	Segment Location
0.647812	29.08%	46.04%	24.40%	25.00%	Middle Fork Flathead River
1.319609	26.45%	40.24%	25.94%	33.35%	Grinnell Dr.
1.720725	32.12%	37.21%	25.89%	36.89%	
2.030464	39.90%	40.43%	25.02%	34.91%	West Entrance
2.378919	39.88%	40.45%	25.03%	34.97%	
2.552188	20.13%	31.08%	24.98%	18.92%	West Entrance to Quarter Circle
2.668556	16.82%	28.73%	33.21%	16.17%	
3.241568	24.62%	31.57%	16.87%	22.81%	Quarter Circle to GTSR and Camas
4.631948	28.79%	36.16%	22.90%	29.34%	Apgar
10.26612	19.43%	15.33%	22.92%	12.67%	Lake McDonald to Sprague Creek
10.37813	41.68%	27.88%	17.10%	20.16%	
10.73111	44.55%	31.30%	18.66%	20.53%	Sprague Creek to Boatman's Lodge
10.91217	35.44%	22.86%	19.80%	18.74%	Lake McDonald Lodge
10.92045	35.68%	18.96%	14.17%	17.22%	
10.95689	52.18%	19.15%	29.80%	17.30%	
10.97886	48.74%	19.33%	29.95%	18.46%	
11.1368	14.79%	20.07%	29.99%	40.95%	
12.06369	16.52%	25.48%	29.19%	19.37%	Lake McDonald to McDonald Creek
14.24756	19.22%	33.49%	29.21%	29.38%	McDonald Falls/Creek
16.59241	22.64%	23.85%	29.49%	18.51%	McDonald Creek to Avalanche
16.9071	41.26%	29.43%	22.19%	26.93%	Avalanche Creek
17.09204	31.62%	38.25%	22.24%	30.65%	

Milage	2017	2018	2019	2021	Segment Location
17.12845	47.50%	38.99%	22.88%	31.72%	Avalanche Creek cont.
17.23146	37.36%	28.65%	22.03%	31.29%	
17.28172	35.70%	28.90%	21.64%	32.09%	
17.31033	36.53%	28.32%	24.04%	31.11%	
17.68699	39.68%	30.68%	23.50%	30.73%	
18.73454	22.91%	35.79%	29.10%	28.88%	Red Rocks
20.06191	17.80%	20.73%	28.94%	25.78%	McDonald Creek after Red Rocks
20.06842	15.75%	21.12%	28.63%	17.02%	
20.32418	15.68%	21.29%	28.26%	17.22%	McDonald creek to Patrol Cabin
21.15403	20.17%	17.54%	31.99%	15.30%	Patrol Cabin
21.16904	18.18%	20.35%	16.56%	27.81%	Logan Creek Bridge
22.74433	14.25%	44.44%	39.71%	46.17%	After Logan Creek Bridge
22.9549	17.25%	19.10%	20.58%	23.49%	After Logan Creek Bridge to Packer's Roost Road
25.47211	28.73%	28.23%	20.44%	18.80%	Before West Tunnel
25.53191	25.02%	26.96%	16.62%	31.07%	West Tunnel
26.47536	31.97%	39.74%	21.37%	43.42%	The Loop
32.28948	29.96%	38.39%	20.63%	40.73%	The Loop to Haystack Creek
33.09536	24.91%	18.01%	25.97%	32.70%	After the Loop
33.12241	33.95%	13.89%	40.80%	30.39%	Turn with waterfall
35.8888	27.46%	31.07%	41.82%	9.80%	Big Bend/3 Arches/Weeping Wall
35.92602	34.20%	30.43%	39.60%	22.08%	Turn with waterfall
40.2331	37.66%	29.94%	39.37%	34.22%	Oberlin Bend before Logan Pass

Milage	2017	2018	2019	2021	Segment Location
40.91837	45.42%	24.76%	39.11%	56.11%	Logan Pass (near lot)
41.46914	43.64%	47.17%	38.02%	21.79%	Logan Pass (after lot)
42.25413	35.82%	36.50%	28.09%	36.26%	Lunch Creek
42.36094	41.21%	24.72%	40.87%	29.47%	Tunnel
44.04003	30.09%	52.38%	39.91%	31.48%	Siyeh Pass
45.29572	29.66%	24.18%	28.05%	21.37%	Siyeh Pass to Jackson Glacier Overlook
45.62247	32.65%	27.70%	27.81%	38.32%	Jackson Glacier Overlook
45.86965	36.11%	27.33%	32.33%	38.47%	Deadwood Falls trailhead (before trail)
46.07126	28.01%	28.42%	20.27%	37.75%	Deadwood Falls trailhead(after trail)
47.95757	24.87%	27.26%	27.54%	34.44%	Jackson Glacier Overlook to St. Mary River
48.62443	34.29%	32.37%	27.33%	28.19%	St. Mary Falls trailhead
48.65704	27.38%	28.72%	49.26%	38.04%	Baring Creek Bridge
48.82772	29.37%	34.10%	16.70%	33.84%	St. Mary Falls to Sun Pt.
48.9843	26.58%	32.22%	27.13%	29.11%	Before Sun Pt. Rd
49.02968	23.71%	30.41%	26.83%	21.37%	Sun Pt. Rd (in between segment)
51.97562	29.39%	22.53%	23.10%	27.11%	After Sun Pt. Rd
52.49714	49.13%	27.95%	26.65%	13.86%	Rising Sun Dock Rd (before rd) - Golden Staircase
52.64525	44.01%	35.12%	26.46%	20.16%	Rising Sun Dock Rd (after rd) to Rising Sun Rd2 (before rd)
52.66411	38.44%	27.44%	26.42%	23.32%	Rising Sun Rd1 (after road)
52.68041	36.67%	27.28%	44.15%	22.86%	Rose Creek
52.80287	35.31%	26.84%	41.83%	22.45%	Rising Sun Rd2(before rd)
52.9008	34.60%	46.53%	41.83%	16.13%	Rising Sun Rd2 (after road)

Milage	2017	2018	2019	2021	Segment Location
54.37336	29.33%	13.45%	25.97%	12.02%	Along St. Mary Lake
54.57479	39.02%	31.66%	30.03%	8.28%	St. Mary Campground (before entrance)
54.73042	20.59%	36.51%	31.63%	22.10%	St. Mary Campground (after entrance)
54.78174	46.80%	20.58%	36.72%	33.88%	St. Mary River
55.12237	48.24%	44.93%	35.32%	20.77%	St. Mary River to Visitor Center
55.7146	37.86%	40.64%	34.96%	41.18%	St. Mary Entrance
55.97575	39.29%	40.60%	15.12%	41.14%	St. Mary Entrance
56.56187	42.18%	40.75%	33.73%	41.26%	
56.97701	57.86%	43.78%	34.89%	39.76%	
57.63237	54.80%	49.72%	34.09%	39.19%	St. Mary area roads to Divide Creek
57.669	44.35%	21.74%	45.46%	40.50%	Divide Creek
57.85593	50.51%	25.93%	46.95%	45.30%	St. Mary Lodge
57.89779	56.05%	22.09%	33.33%	33.94%	St. Mary Lodge
58.33742	44.09%	52.25%	33.29%	35.50%	

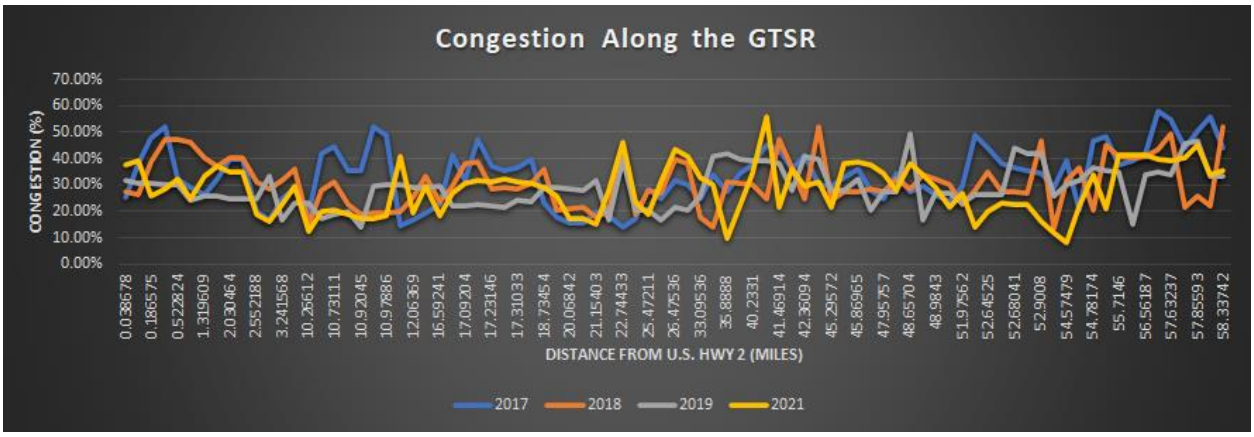

Figure S9. Congestion along the GTSR by mile from U.S. HWY 2.

Logan Pass Visitor Center Parking Lot

We also looked into arrival times at Logan Pass Visitor Center parking lot as part of our GTSR analysis. *Figure S10* below shows the non-pass-through zone which we used in that analysis.

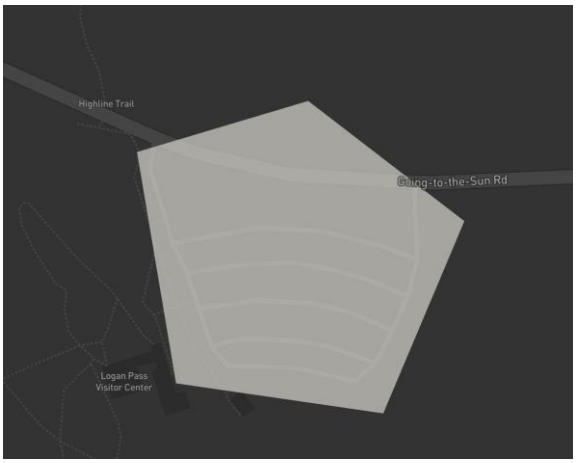

Figure S10. Zone used for Logan Pass Visitor Center Parking Lot entrance and exit times. This analysis captured <1000 trips (for 2021) and 1000 trips (for 2019).

Time to Logan Pass Road Segment

We ran an Origin-Destination Analysis with the West Entrance as the origin and the Logan Pass Road Segment as the destination. From this, we used Trip Attributes to determine the times that visitors took to get from the West Entrance to the road. We did this for multiple times during the day for both 2019 and 2021 to show the impacts of the TES. *Figures S11-S13* show these analyses.

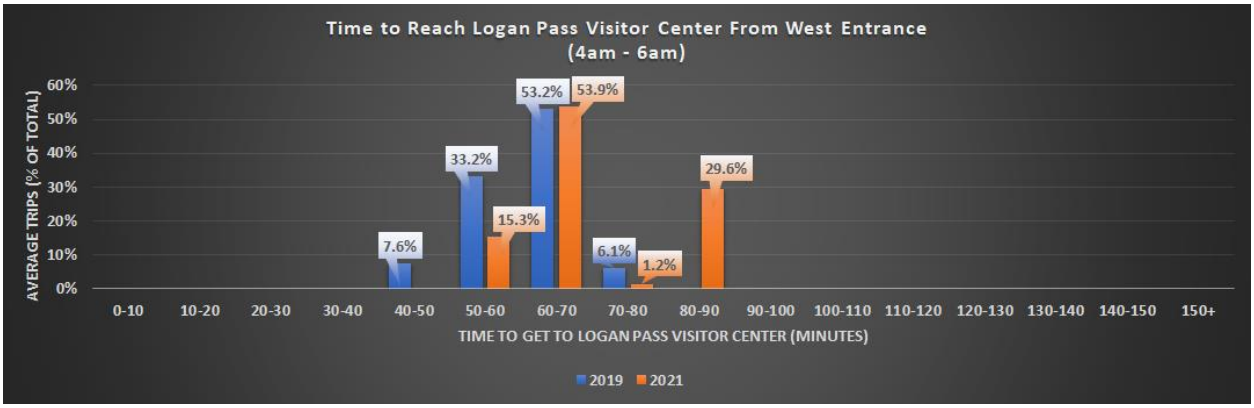

Figure S11. This graph shows the distribution of the times it took trips to reach the Logan Pass road segment shown in Figure S10 *between the hours of 4 AM and 6 AM. This analysis tracked approximately 400 trips for 2019 and 1000 for 2021*

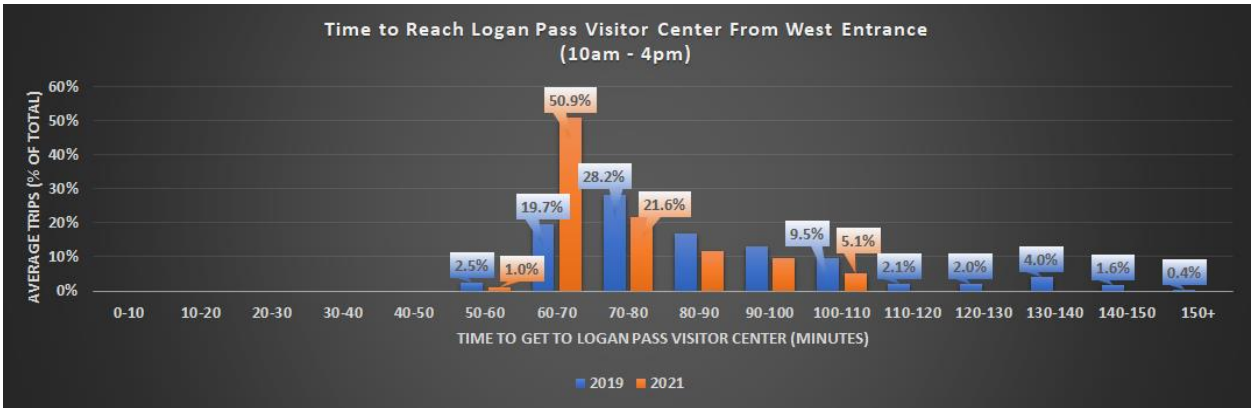

Figure S12. This graph shows the distribution of the times it took trips to reach the Logan Pass road segment shown in Figure S10 *between the hours of 10 AM and 4 PM. This analysis tracked approximately 6700 trips for 2019 and 3000 for 2021*

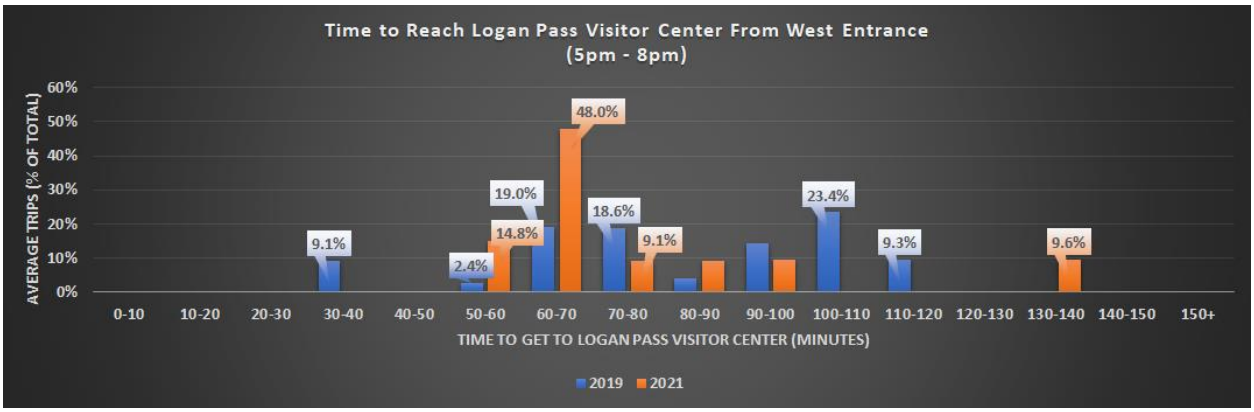

Figure S13. This graph shows the distribution of the times it took trips to reach the Logan Pass road segment shown in Figure S10 *between the hours of 5 PM and 8 PM. This analysis tracked approximately 1200 trips for 2019 and 2021*

Pedestrian Activity

Through an Origin-Destination Analysis with the origin over the Logan Pass Visitor Center parking lot and the destinations being unidirectional passthrough zones along the beginnings of the Hidden Lake trail and Highline Trail, we were able to monitor pedestrian activity over 2019 and 2021 for the two trails. As shown in *Figure S14*, there was a 25% increase in the percentage of visitors hiking the Hidden Lake trail from 2019 to 2021. This could be due to an increase in parking lot availability, allowing visitors to do more than one shorter hike per day. For example, a person heading in from the St. Mary Entrance could choose to do the St. Mary Falls hike, then with the rest of the day, head over to Logan Pass to do another shorter hike. In 2019, where Logan Pass is generally filled up for the entirety of the day, visitors may want to choose a hike that will take them all day because they believe they will not be able to find a parking spot in another lot after completing a short hike.

Figure S14. Distribution of pedestrian traffic to the trailheads at Logan Pass. Consists of approximately 300 pedestrian trips for each year on each trail.

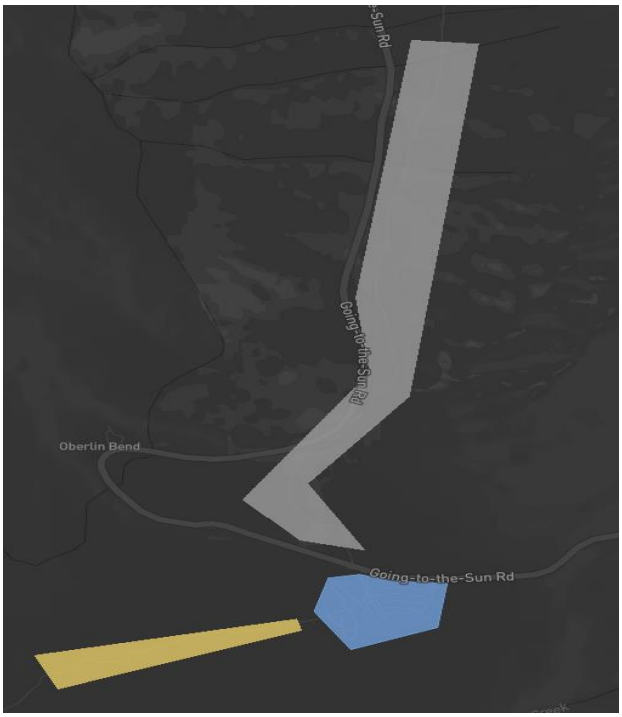

Figure S15. Zones used for the 'Distribution of Pedestrians to Logan Pass Trailhead' passthrough zone analysis.

Surrounding Communities

To collect data on where vehicles traveled after turning around, we placed non-pass-through polygon zones across the popular surrounding communities around the West Entrance. From our previous analyses, we know that it is very unlikely for a trip to continue all the way to smaller parts of the Park on the East side in one trip, therefore only larger communities around the West Entrances were chosen for turnaround destinations. Below, the zones are shown in three different figures (*Figures S16-S18)*. The blue zone around the Corral represents the origin for where vehicles get turned away and these new trips start. The green, yellow, and red zones represent destinations. The more red the color of the zone, the more trip traffic a destination has.

Figure S16. Origin Zone of the Turnaround origin destination analysis around the Park Corral

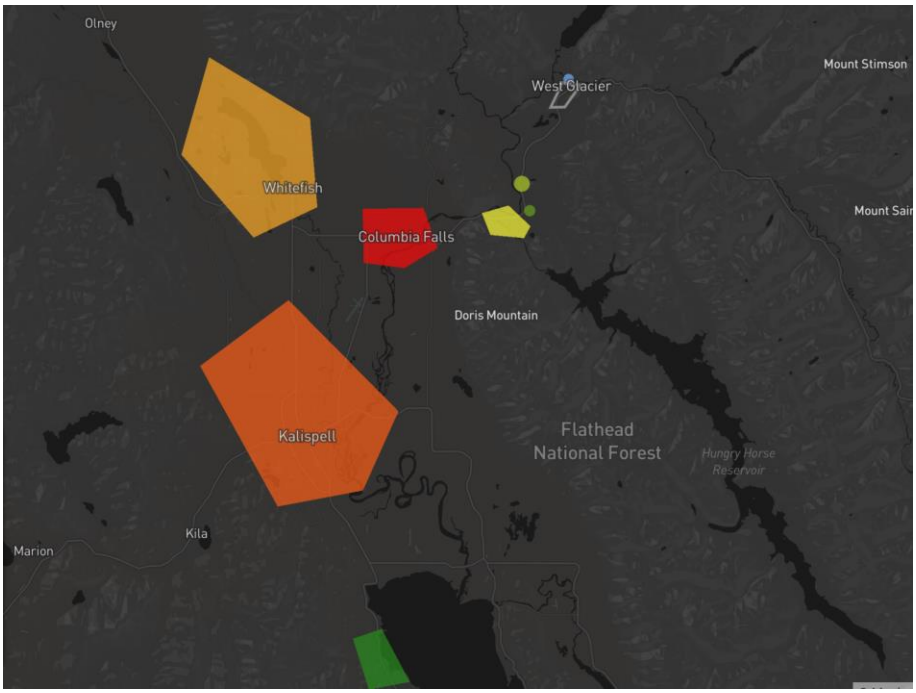

Figure S17. An overview of the origin zone and destination zones used in the turnaround origin destination analysis. The zones highlighted red represent higher amounts of traffic (see Columbia Falls)

Figure S18. A zoomed in view of the above figure used for the same analysis, focusing on the closer nearby communities and West Glacier

Traveler Attributes

Looking more closely into traveler attributes, through the Origin Destination analyses of the West Entrance to GTSR, we tracked the average trip duration and trip length over 2019 and 2021 to compare the impacts of the reservation system on these attributes. As shown below in *Figures S19 and S20*, trip duration and length are similar. The only small difference lies in the first group, the 0-10 minutes on the trip duration and the 0-5 mile group for trip length. This may be suggesting that people are stopping earlier, and therefore perhaps more frequently, along the GTSR. This could potentially be due to less congestion and more parking availability along the road, but more evidence would be needed to support these claims.

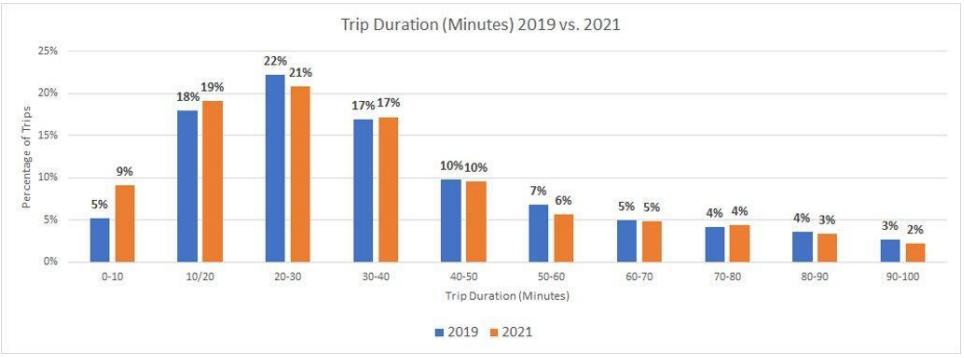

Figure S19. Average trip duration in minutes from the west entrance along GTSR in 2019 and 2021

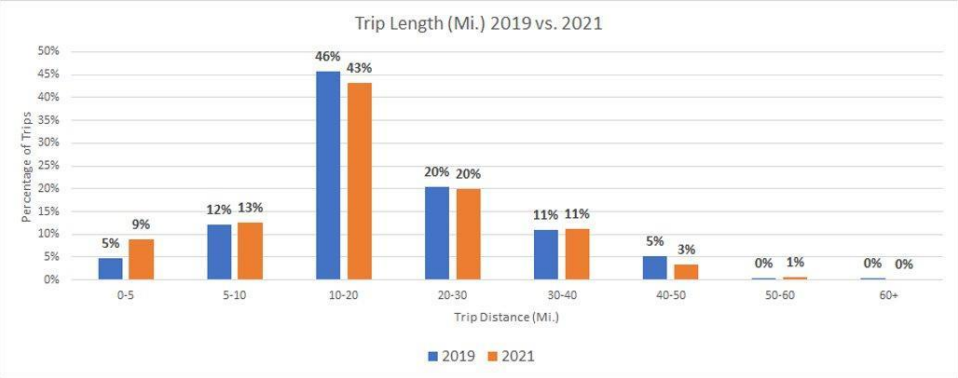

Figure S20. Average trip length in miles from the west entrance along GTSR in 2019 and 2021

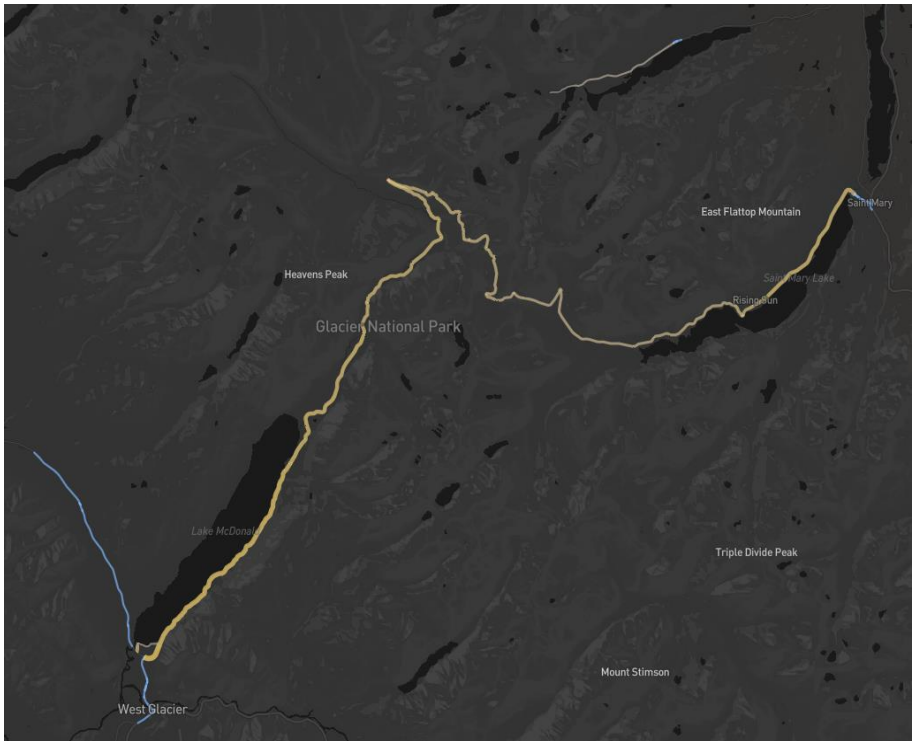

Figure S21. The Origin destination analysis zones are used to gather trip attributes and demographic data. All entrances to the park (except Two Medicine due to its small size resulting in coverage review) are origins, and destinations are all roads within the park. The trip count was over 300,000 for each year.

Home Locations

In the process of compiling trips, SLD can incorporate home and work locations associated with recorded devices. These home and work locations are determined based on daily patterns for each device. This data still remains anonymous. In this analysis on home location data, we used an Origin-Destination Analysis to measure trips that went through any entrance and ended in the park. From this, SLD created a list of the top 1000 home location zones for these visitors. The figures below show the top 1000 home location zones for 2019 (*Figure S22),* and for 2021 *(Figure S23)*. Red zones represent zones of high home location, while green represents zones of low volume of home locations. From this, the table of the top 10 state home locations could be created.

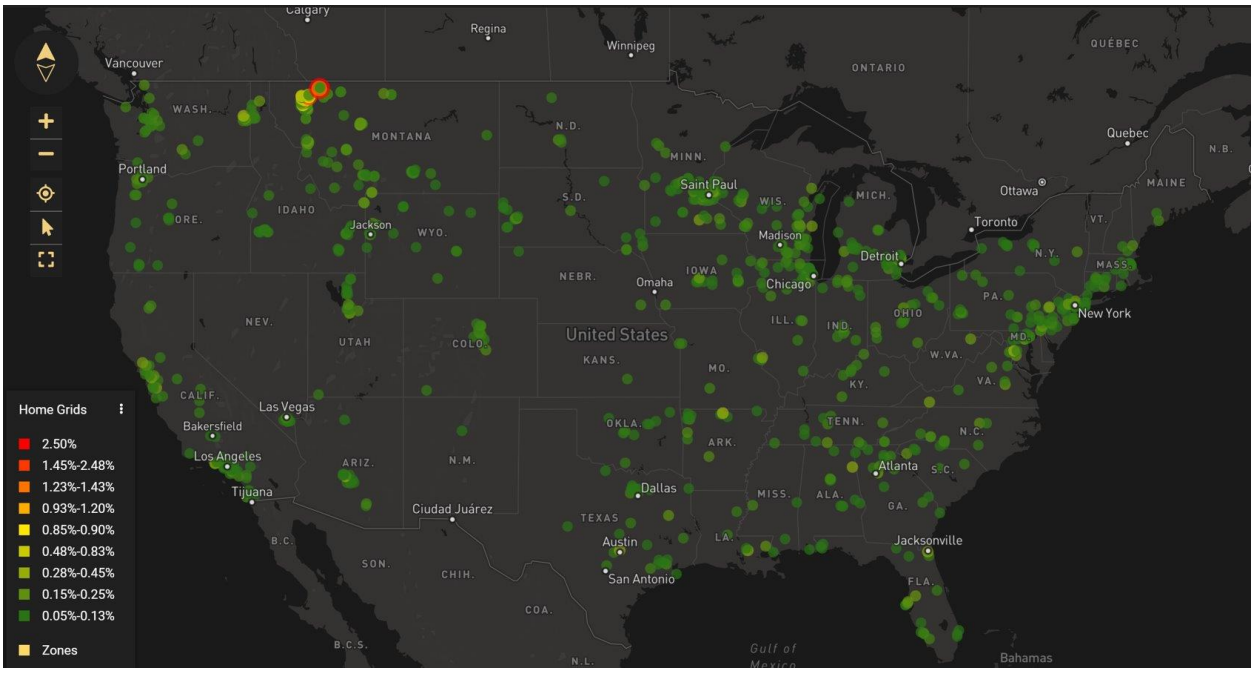

Figure S22. Distribution of home locations of trips that entered the parkthrough the West Entrance or the St. Mary entrance for 2019, capturing 17,000 trips.

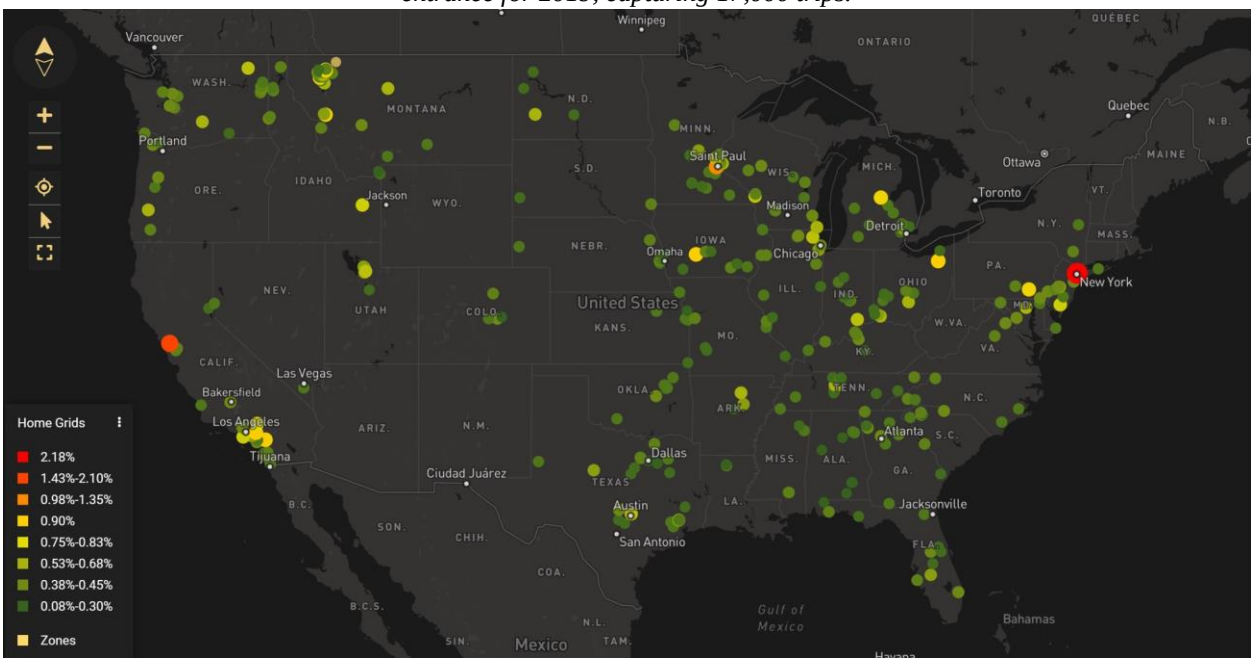

Figure S23. Distribution of home locations of trips that entered the park through the West Entrance or the St. Mary Entrance for 2021, capturing 11,000 trips.

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