



Kenai Fjords National Park Traffic Classification and People-Per-Vehicle Survey

2019 Summary Report

Natural Resource Report NPS/KEFJ/NRR—2021/2223



ON THE COVER

Cars parked in the Exit Glacier Area parking lot of Kenai Fjords National Park
Tyler Balstad/NPS.

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Abstract

The objectives for the Traffic Classification and People-Per-Vehicle Survey in the Exit Glacier Developed Area of Kenai Fjords National Park (KEFJ) were to: 1) evaluate the ability of the Omega X3 traffic classifier to differentiate commercial and private vehicle use at Exit Glacier; 2) update the park's people-per-vehicle (PPV) factor; 3) explore the other capabilities and uses of the classifier and its potential utility to KEFJ.

This study included collection of observational data on vehicle class, arrival time, lane of travel, number of axles, and people-per-vehicle. The results of the observational data were compared with the classifier's own data in order to assess the classifier's accuracy. The classifier was found to be 99.5% accurate at counting the number of vehicles entering the park and 94.8% accurate at properly classifying vehicles by axle length. The data gathered on people-per-vehicle were used to calculate new PPV factors and update the park's method for estimating visitor use in the Exit Glacier Area. The overall PPV factor was found to have increased from 2.9 to 3.5, and new PPV factors were calculated for each specific vehicle class. I also analyzed data from the classifier to see if it could help assess modes of visitor access, identify times of congestion in the parking lot, and monitor long term changes in vehicle class composition.

Distinguishing between commercial and non-commercial vehicles is beyond the ability of the classifier (Objective 1). This is because commercial and non-commercial vehicles can be of similar dimensions despite their difference in use, in particular certain passenger vans. Tour buses are a notable exception and were consistently distinguished by the Omega X3. However, using an updated PPV for each individual vehicle classes, the Omega X3 is able to provide a more precise estimate of visitation as well as patterns of visitation reflected through vehicle use (e.g. whether tourists arrive by tour bus or in passenger cars, Objective 2). Finally, the Omega X3 produces data that can be used to analyze changes in vehicle numbers each hour, each day, day of the week, or over longer periods of time. This added precision will help the park make more informed decisions related to vehicle and visitor management in the Exit Glacier Area.

List of Acronyms

KEFJ: Kenai Fjords National Park

PPV: People-per-vehicle

CAF: Classification accuracy factor

CVF: Classification volume factor

FHWA: Federal Highway Administration

RV: Recreational vehicle

ADT: Average daily traffic

AHT: Average hourly traffic

DOW: Day of the week

Introduction

Kenai Fjords National Park is located in south-central Alaska, near the City of Seward. Thousands of visitors come to the park every year to explore its wild beauty and witness the raw power of its glaciers. The Exit Glacier Area of KEFJ is the only part of the park accessible by road. The majority of visitation to this area occurs from May through September when the Herman Leirer Road leading into the park is open to vehicle travel. In particular, June, July, and August typically represent the prime travel period for tourists to Seward. Visitors to the Exit Glacier Area arrive by a variety of vehicles, including motorcycles, large tour buses, private shuttles, and passenger vehicles. Vehicle volume in the summer months has been trending upwards since 2010. In 2010, 43,151 vehicles were counted between June and August as compared to 54,121 in 2019 (NPS, 2019). There is a single parking lot to accommodate these vehicles, which frequently operates over capacity.

In response to data gaps identified in a Federal Highways Administration's Western Federal Lands Division Exit Glacier Area transportation feasibility study (Quinn et al., 2019) and in preparation for a frontcountry management plan, KEFJ purchased and installed an Omega X3 vehicle classifier on the road leading into the Exit Glacier parking lot. The three objectives for installing and testing the classifier were to: 1) see if commercial and non-commercial vehicles could be differentiated; 2) to update the park's people-per-vehicle factor (PPV); and 3) to explore the overall capabilities and utility of the classifier. The PPV factor is used in conjunction with vehicle volume data to estimate the number of visitors to the Exit Glacier Area. To keep this factor current it should be updated on a regular cycle to capture changes in vehicle occupancy over time and to provide the most current PPV estimate. Completing a PPV survey at least every 7 to 10 years, unless obvious changes in visitor access occur, should be adequate. The PPV factor was last updated in KEFJ in 2007.

There were several additional goals for this survey. These goals included determining if the classifier could provide greater insight and a baseline into vehicle volume composition and modes of access, testing the accuracy of the Omega X3 in both volume and vehicle classification, determining if data collected by the vehicle classifier could provide information useful to help park managers address parking lot congestion, and identify other useful functions of this device for management at KEFJ.

The park currently uses a Diamond Traffic Tally 77 (TT-77) vehicle counter to count number of vehicles entering the park. The TT-77 counts each vehicle entering the Exit Glacier parking lot but cannot distinguish between different types of vehicles. Whether the vehicle is a large multi-passenger tour bus or a motorcycle, they are still counted as a single vehicle. The Omega X3, by contrast, can gather much more detailed information, including vehicle class, timing, speed, and more. Understanding what new data the Omega X3 could provide to park management over the TT-77 was a key aspect of this study.

Methods

Installation

The vehicle classifier on May 27, 2019 was installed along the entrance road to the parking lot, Site 1 (Figure 1). The road tubes crossed the fork of the parking lot entrance road that divides inbound traffic. This location was chosen to capture the difference in use between the right-hand lane (Lane 1) and the left-hand lane (Lane 2). Anecdotal evidence suggested that capturing the difference in use between these two lanes could distinguish commercial and private vehicle traffic. Currently, a sign directing traffic at Site 1 instructs “tour buses” into Lane 1, and “Parking” into Lane 2.



Location of Site 1. The classifier road tubes can be seen crossing each lane. The sign directs tour buses into the right-hand lane (Lane 1) and all other vehicles into the left-hand lane (Lane 2).

This site was eventually abandoned after it was determined that tour buses and some large campers/small buses were not registering correctly. This error was due to a slight curve in the road which caused some vehicles with long axels to cross the road tubes at an angle, resulting in inaccurate data. Additionally, observations showed that many private vehicles were utilizing Lane 1, which made distinguishing commercial and non-commercial use by lane of travel untenable.



Figure 1. Locations of the Omega X3 vehicle classifier and pneumatic road tubes at Site 1 and Site 2.

On July 12, 2019 the classifier was moved farther east on the parking lot entrance road to Site 2 (Figure 1), along a straight section of the inbound road into the parking lot. This location was chosen so that all vehicles would maintain travel perpendicular to the road tubes, reducing errors and misclassification of larger vehicles. After two weeks of monitoring, this site showed fewer classification errors than Site 1, and was utilized for the remainder of the study period.

Data Collection

The Omega X3 vehicle classifier gathers data by using a set of rubber pneumatic tubes that are stretched across a road surface. Compressed air is sent through these hollow tubes to a sensor in the classifier when struck by the tires of vehicles driving along the roadway. Information regarding vehicle length, number of axles, speed, lane of travel, time of crossing, and other types of data, can be calculated by measuring the gaps in time between these compressed air signals. To obtain accurate data, vehicles must drive perpendicularly over the road tubes and be travelling at a sufficient speed (Weible 2016, Diamond 2019).



Diamond Omega X3 vehicle classifier with four road tubes connected (NPS/Tyler Balstad).

To test the volume and classification accuracy of the Omega X3, a series of calibration surveys were conducted. These involved performing in-field observations of vehicles crossing the road tubes and comparing these data with those collected by the classifier. The crossing time, vehicle class, number of axles, and presence or absence of a trailer for every vehicle that drove over the road tubes were recorded. Any aspects about a vehicle's driving pattern that could have affected data collection by the classifier, such as stopping over the tubes, driving slowly, or not crossing perpendicular to the road tubes, was noted.

Surveys to update the park's PPV factor were performed separately from the calibration surveys until July 23. The data collected for PPV included vehicle class, number of passengers, and whether the vehicle was commercial or non-commercial. These data were obtained once a vehicle entered the Exit Glacier parking lot proper. After several PPV surveys, it was deemed more efficient to conduct both surveys at the same time since they involved gathering similar data. The combined surveys were done from June 23 until the end of August.

For the combined surveys, vehicles were stopped before they reached the road tubes to determine how many people were in each vehicle. Vehicles then proceeded across the road tubes and the remaining calibration surveys were made. Stopping vehicles 20 yards before the road tubes allowed them to regain an adequate speed for the classifier to gather accurate data. Industry experts suggest vehicles should be travelling at least 7 miles per hour when crossing the road tubes for pneumatic

traffic devices (Diamond Traffic Products, 2019). In total, 25 calibration surveys and 22 PPV surveys (Table 1) were completed.

Table 1. Number of Surveys for Classifier Calibration and People-Per-Vehicle by Month.

Month	Number of Calibration Surveys	Number of People-Per-Vehicle Surveys
May	2	0
June	9	8
July	8	8
August	6	6
Total	25	22

Starting on May 29, a randomized schedule was constructed to determine when to perform these surveys. Surveys lasted a minimum of one hour and occurred between 8:30 a.m. to 4:00 p.m., the busiest hours for vehicle traffic in the Exit Glacier Area. Although the minimum survey time was one hour, surveys typically lasted around 2 hours to increase the vehicle sample size, and some surveys lasted longer than 2 hours as time allowed. Calibration samples were collected at least once for each day of the week (Table 2). For people-per-vehicle surveys, data were collected at least once for each day of the week except for Wednesday due to scheduling and time constraints.

Table 2. Number of Surveys for Calibration and People-Per-Vehicle by Day of Week.

Weekday	Number of Calibration Surveys	Number of People-Per-Vehicle Surveys
Sunday	7	7
Monday	2	4
Tuesday	3	3
Wednesday	1	0
Thursday	2	1
Friday	3	3
Saturday	5	5

Non-commercial or private vehicles are defined as those vehicles that belonged to private individuals who entered the park for their own recreational purposes, while commercial vehicles were those that belonged to a business and came to the park as part of their business activities. Common examples of commercial vehicles included taxis, vans and small buses carrying guided tour groups, shuttle vehicles belonging to local hotels, and tour buses carrying cruise ship clientele to the park.

The Omega X3 utilizes the Federal Highway Administration (FHWA) Scheme F Report to classify vehicles into 13 distinct axle bins or classes (FHWA, 2014). These classes are based upon number of axles, number of trailers, number of tires, and the general design of the vehicle (Figure 2). Vehicle length is not specifically a feature of the FHWA classification scheme, but vehicles tend to get larger as the class number increases. Although not shown in the figure below, the classifier also records Class 0 vehicles, which represent vehicles that are unable to be positively categorized due to error.

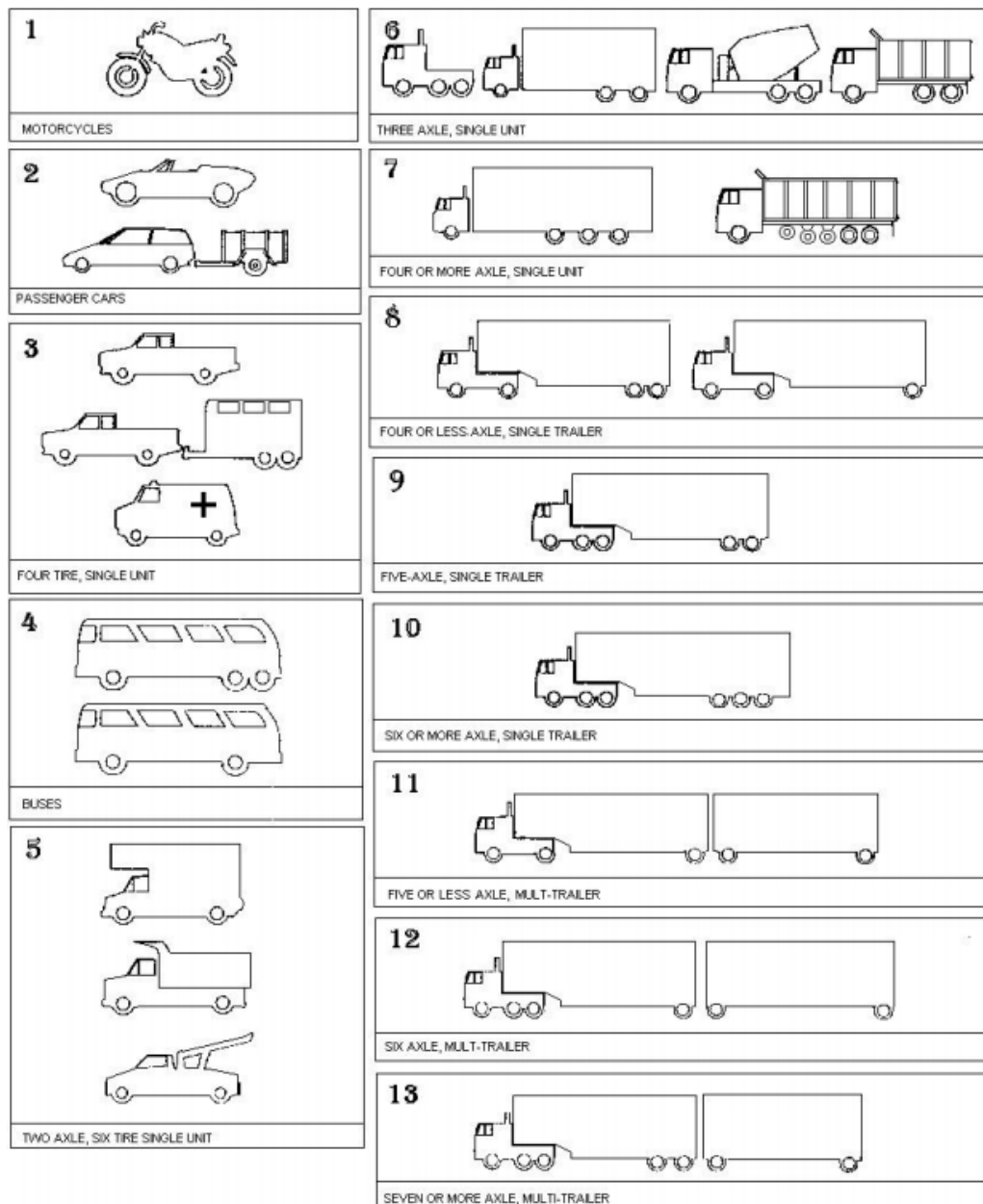


Figure 2. Vehicle classes found in the FHWA Scheme F classification system used by the Omega X3.

Although the FHWA Scheme F Report provides a general overview of the vehicles found within each class, there were several observed vehicle types that were not easily identified using the Scheme

F descriptions. To facilitate better understanding of what types of vehicles fit into each of the 13 vehicle classes, plain speech names for the vehicle classes are used within this report, with specific photo examples in Appendix A. These alternate names help improve clarity, but FHWA names are used when they are more appropriate. These names are meant to be broad generalizations that reflect common-sense perceptions of vehicle classes and should not be thought of as representing all vehicle types for a specific vehicle class. Images found in Appendix A were taken during this study and provide additional visual representations of the different vehicles belonging to each class.

Class 1 Vehicles will be referred to as *Motorcycles*, Class 2 as *passenger cars*, Class 3 as *trucks/vans*, Class 4 as *tour buses*, and Class 5 as *large campers/small buses*. Of the 13 classes, only classes 1–5 were observed in the Exit Glacier Area during the study period. Despite this fact, vehicles registered in classes 6–13 still appeared in the classifier’s data. In total, 30 vehicles were registered in classes 6–13, but did not belong in this classification. All of these vehicles were in classes 2–4, and only five had trailers. Based upon these observations, all vehicles registered in classes 6–13 are treated as an individual vehicle that was misclassified. As no vehicles within classes 6–13 were observed during this survey, these classes will be referred to as *unidentified vehicles*. Class 0 vehicles are also included in the *unidentified vehicles* category. This information is summarized in Table 3 below.

Table 3. FHWA Scheme F vehicle class notation and their corresponding plain speech terms.

Class Number	FHWA Class Number and Name	Plain Speech Name
Class 1	Motorcycles	Motorcycles
Class 2	Passenger Cars	Passenger Cars
Class 3	Four Tire Single Unit	Trucks/Vans
Class 4	Buses	Tour Buses
Class 5	Two Axle Six Tire Single Unit	Large Campers/Small Buses
Class 0, Class 6 – Class 13	Multi-Axle Single or Multi-Trailer	Unidentified Vehicles

Results

Classifier Accuracy

During the survey period, 25 calibration surveys were conducted to test the accuracy of the classifier and document sources of error (Table 4). In total, 18 motorcycles, 1,532 passenger cars, 657 trucks/vans, 11 tour buses, 108 large campers/small buses, and 0 unidentified vehicles were observed crossing the classifier's road tubes. In contrast, during the same study times, the automated classifier recorded 25 Motorcycles, 1,524 passenger cars, 628 trucks/vans, 8 tour buses, 101 large campers/small buses, and 39 unidentified vehicles. Of the unidentified vehicles, the classifier registered 29 as a vehicle in Classes 6–13, a total of 9 as Class 0, and 2 vehicles were not detected at all. Class 0 vehicles are those that cross the road tubes in such a way that they produce insufficient data to accurately classify a vehicle but were still detected by the Omega X3. It is unclear why two vehicles went completely undetected.

Table 4. Summary of observed vehicles and the same vehicles as detect by the vehicle classifier.

Vehicle Class	Motorcycles	Passenger Cars	Trucks/ Vans	Tour Buses	Large Campers/ Small Buses	Unidentified Vehicles	Total
Classifier Counts	25	1,524	628	8	101	40	2,326
Percent	1.1%	65.5%	27.0%	0.3%	4.3%	1.7%	100%
Observer Counts	18	1,532	657	11	108	0	2,326
Percent	0.8%	65.9%	28.2%	0.5%	4.6%	0.0%	100%
Absolute Difference	7	8	29	3	7	40	–

Classifiers are not infallible devices and can have incorrect records for a variety of reasons. To determine the accuracy of the classifier's data, I calculated factors for both classification and volume accuracy using the above data.

The volume accuracy factor (VAF) for the classifier represents how many of the total vehicles driving over the road tubes were detected. The VAF does not consider whether a vehicle was correctly classified. The VAF is calculated by finding the difference between detected and undetected vehicles, dividing by the total number of observed vehicles, and then multiplying by 100 to convert this value to a percent. This is summarized in the formula below. Detected vehicles are those that produced enough accurate information to register as a single timestamp in the classifier data set. Undetected vehicles are those that produced either multiple class 0 timestamps or did not produce any timestamp. During the surveys, nine vehicles produced class 0 records and two vehicles were not detected by the classifier at all, resulting in a total of 11 undetected vehicles. The classifier's VAF was calculated to be 99.1% accurate at detecting vehicle volume.

$$VAF = \frac{(\Sigma Obs. Vehicles - \Sigma Missed Vehicles)}{\Sigma Obs. Vehicles} * 100 = \frac{(2,326 - 11)}{2,326} * 100 = 99.5\%$$

The classification accuracy factor (CAF) was calculated using observational data by subtracting the total number of misclassifications from the total number of observed vehicles, dividing the result by the total number of observed vehicles with classification data, and then multiplying by 100 to convert this value to a percent. The formula for this is presented below with the data used in this report. In total, there were 122 differences in vehicle classification between the classifier and observational data. The classifier has a CAF of 94.8%.

$$CAF = \frac{(\Sigma Obs. Vehicles - \Sigma Misclassifications)}{\Sigma Obs. Vehicles} * 100 = \frac{(2326 - 122)}{2326} * 100 = 94.8\%$$

Of these 122 misclassifications, 4 were misclassified Motorcycles (3.3%), 47 were misclassified passenger cars (38.5%), 54 were misclassified trucks/vans (44.3%), and 13 were misclassified large campers/small buses (10.7%) A specific breakdown of the misclassifications for each observed class are given in Table 5. The largest source of classification error was with passenger cars and trucks/vans.

Table 5. Summary of specific classification errors.

Omega X3 Vehicle Class	Observed Vehicle Class													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	0	4	3	2	0	0	0	0	0	0	0	0	0	0
1	0	0	6	4	0	1	0	0	0	0	0	0	0	0
2	0	0	0	36	0	3	0	0	0	0	0	0	0	0
3	0	0	22	0	1	1	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5	0	0	1	5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	2	1	0	0	0	0	0	0	0	0	0
8	0	0	2	2	0	4	0	0	0	0	0	0	0	0
9	0	0	0	0	1	1	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Table 5 (continued). Summary of specific classification errors.

Omega X3 Vehicle Class	Observed Vehicle Class													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	13	1	1	1	0	0	0	0	0	0	0	0
Blank	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Errors Per Class	0	4	47	54	4	13	0	0	0	0	0	0	0	0
Total Classification Errors	122	–	–	–	–	–	–	–	–	–	–	–	–	–

Traffic Data

Data from the classifier can be utilized to calculate different indices that depict traffic conditions in the Exit Glacier Area.

Average Hourly Traffic

Average hourly traffic (AHT) is a measurement of the average number of vehicles per hour that cross the road tubes. AHT can be used to determine busiest hours of the day and anticipate congestion events caused by an increase in traffic flow. To calculate AHT, the total number of vehicles are counted per hour and then divided by the total number of sample days. For example, in June a total of 612 vehicles were counted between 8:00 a.m. – 8:59 a.m. over the 30 days of this month. This is expressed in the formula below, using the data from June as an example.

$$AHT = \frac{\Sigma \text{ Hourly Vehicles}}{\Sigma \text{ Days}} = \frac{612}{30} = 20.4$$

Traffic volume data from the vehicle classifier shows that AHT was highest between 9:00 a.m. and 4:00 p.m., with the busiest hour for vehicle visitation occurring at 11:00 a.m. (Figure 3). Noticeable variations exist from month to month. June visitation is busiest at 11:00 a.m. with a second spike in visitation occurring at 3:00 p.m. July was also busiest at 11:00 a.m., but generally tapers off in visitation after that time and does not have any other pronounced spikes in visitation. August visitation was also highest at 11:00 a.m., although more visitors arrive prior to 10:00 a.m. in August compared to June and July.

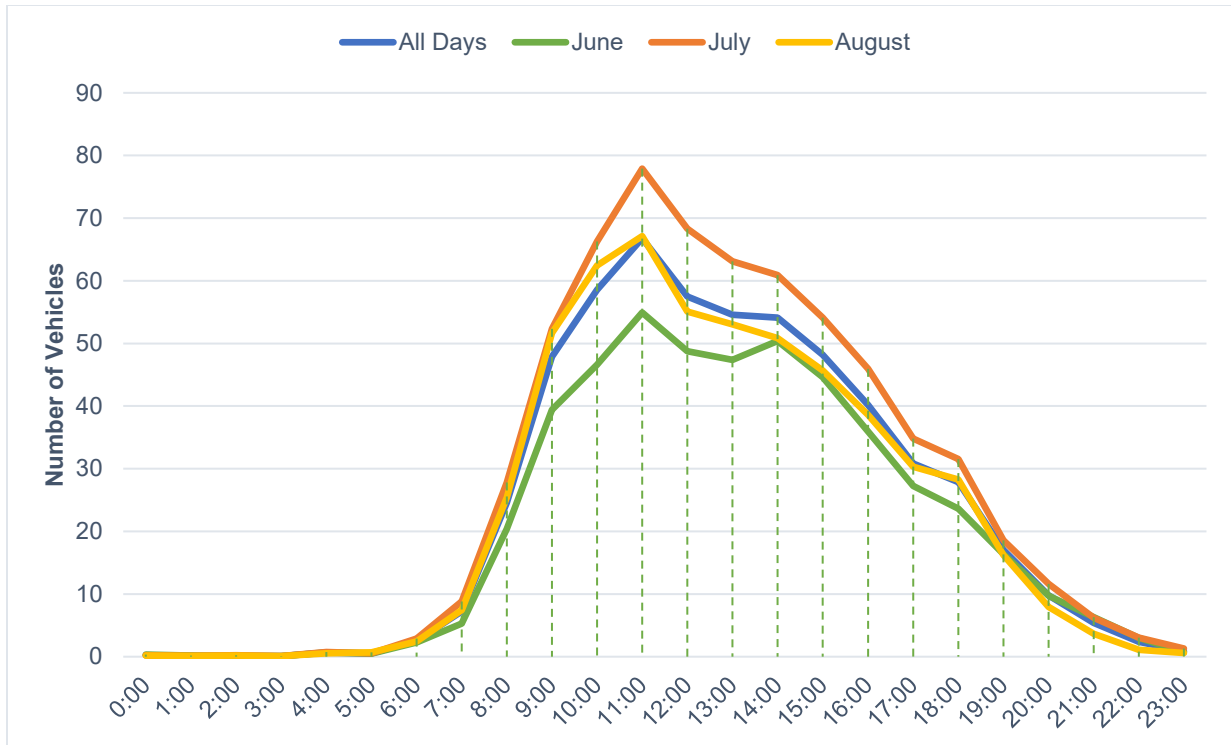


Figure 3. Average Hourly Traffic (AHT) counts of vehicles entering the Exit Glacier Area parking lot for the entire study duration.

Average Daily Traffic

Average Daily Traffic (ADT) is another useful way to interpret traffic volume data (Figure 4). ADT represents the average number of vehicles crossing the road tubes according to the day of the week. To calculate ADT, the total number of vehicles recorded for a specific day of the week (DOW) are divided by the instances of that day of the week during the study period. This formula is shown below, with example data from every Sunday between June and August 2019. Average daily traffic was highest on Friday, Saturday, and Sunday for the entire season of 2019.

$$ADT = \frac{\Sigma \text{Vehicles DOW}}{\Sigma \text{DOW}} = \frac{7,730}{13} = 594.62$$

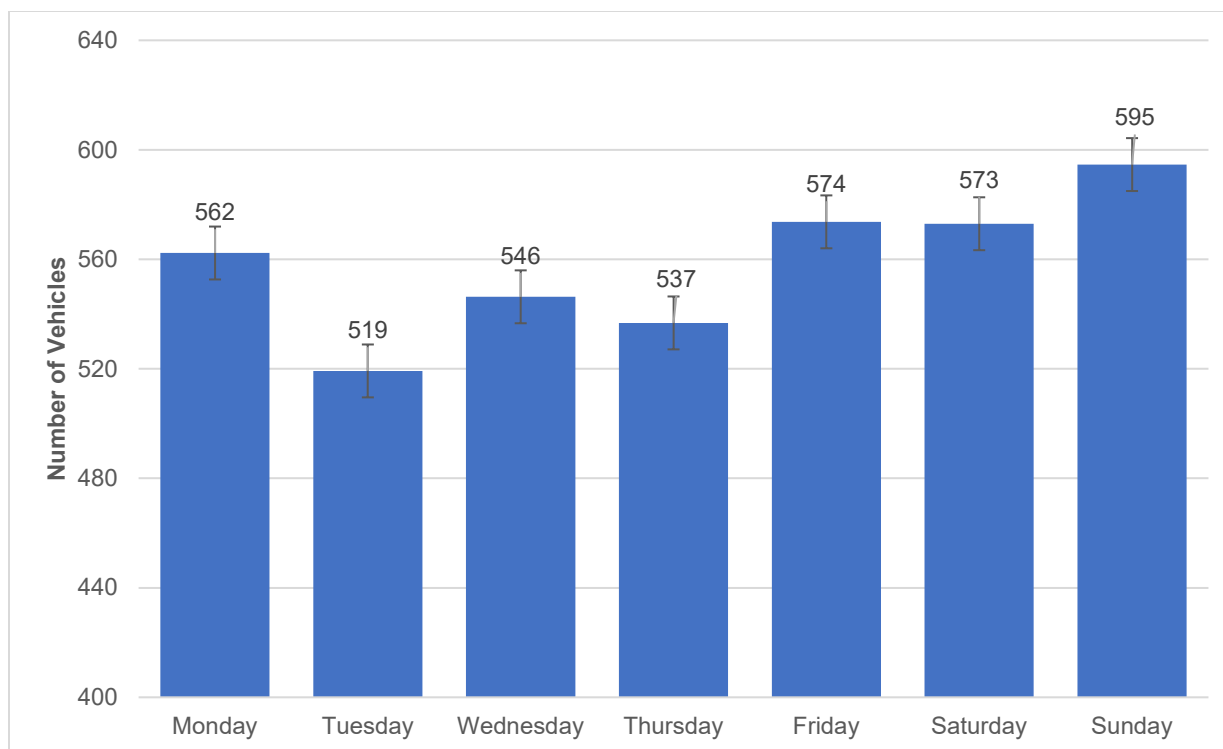


Figure 4. Average Daily Traffic (ADT) counts of vehicles entering the Exit Glacier Area parking lot. Data is from both Sites 1 and 2 from June 1, 2019 to August 31, 2019.

While looking at ADT across the entire season can be useful for a very general understanding of traffic by day of the week, more specific patterns can be uncovered by examining the ADT for each month. The ADT for each month with full data, being June, July, and August, had considerable variation (Figure 5). In July, visitation was highest from Friday through Sunday. The least busy day was Tuesday (ADT=427), while the busiest day was Sunday (ADT=554). The range of differences for ADT in June is 127 vehicles.

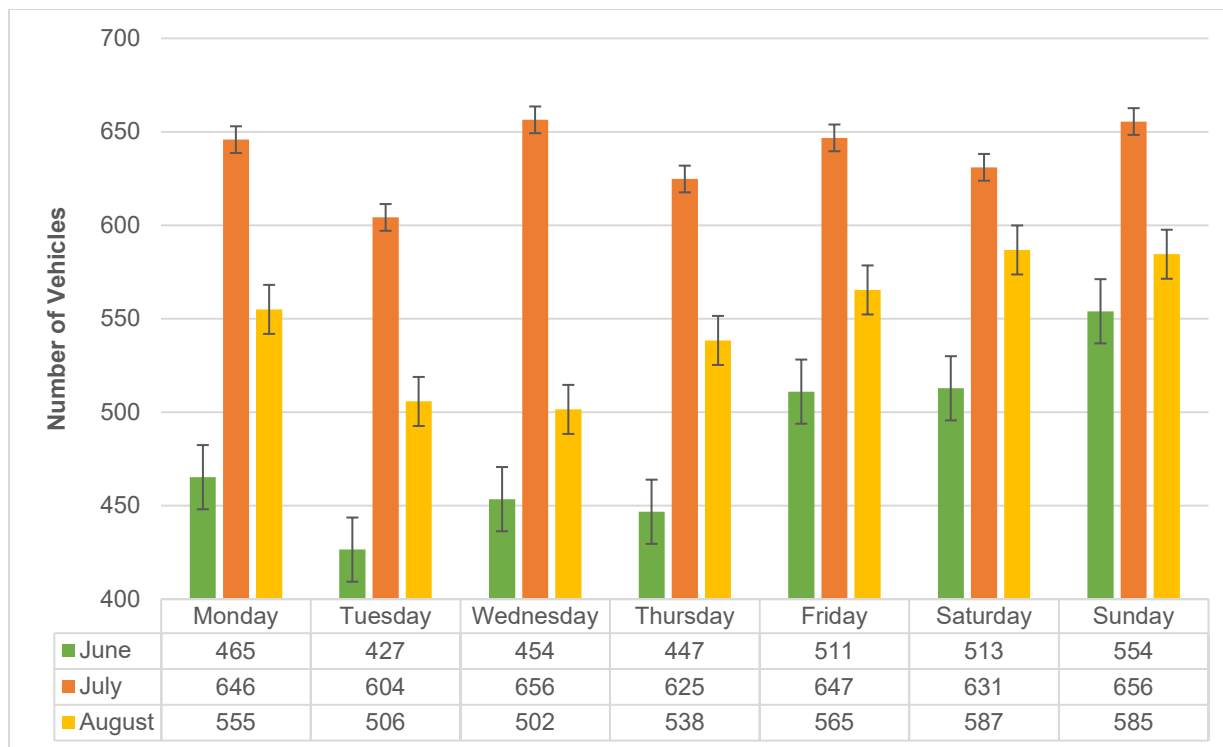


Figure 5. Average Daily Traffic (ADT) by month and day of the week.

July had much higher ADT for all days and less variation between days. The least busy day of the week in July was Tuesday (ADT=604), while the busiest days were both Sunday (ADT=656) and Wednesday (ADT=656). The range of differences for July is 52 vehicles, less than half of June's range.

In August, the least busy day was Wednesday (ADT=502), whereas the busiest day was Saturday (ADT=587). The range of differences for this month is 85 vehicles, showing an increased gap between the busiest days and least busy days compared to July.

Daily Vehicle Volume

The daily vehicle volume (DVV) is the total number of vehicles counted for a specific day. This metric is another useful tool that the classifier can provide and is an index of total visitation. The DVV in the Exit Glacier Area tended to increase from the beginning of the traffic study on June 1 and began to decline towards the end of the study on August 31 (Figure 6). Visitation tended to increase through June and was relatively stable throughout most of July. In the first half of August visitation was relatively stable, but then noticeably declines and increases again in the second half of the month. This saddle in visitation was likely due to the hazardous air quality in Seward during this time from the Swan Lake Fire. Across all three months, daily visitation was variable.

Peak visitation occurred on July 5, with a total of 822 vehicles detected on that day. The two days with the lowest vehicle volume were May 29 and August 27, with a total of 234 vehicles for each day. The total number of recorded vehicles for the study period was 52,035.

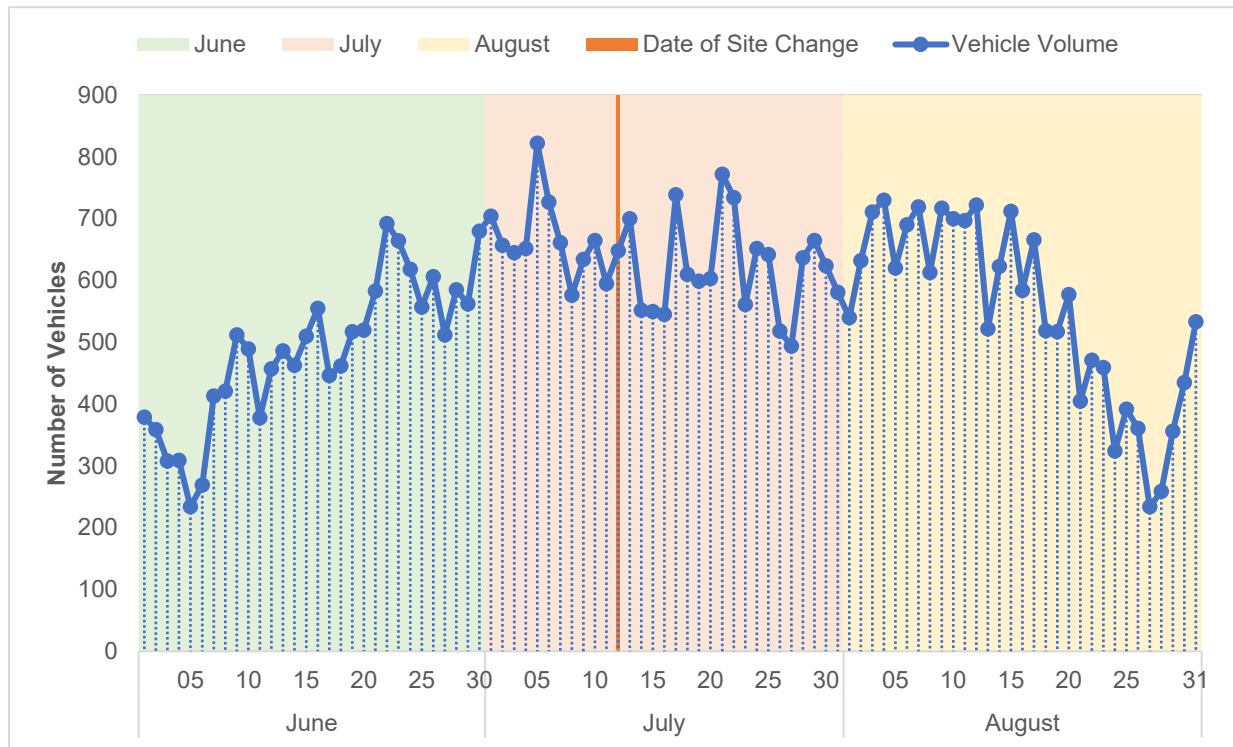


Figure 6. Daily vehicle counts for all vehicle classes.

Using the classifier's data, specific DVV counts for each vehicle class were also discernable. These data are represented in Figure 7. Visitation for passenger cars and trucks/vans tended to follow the same trend. These vehicles increased in volume throughout June, peaked in volume during July, then decreased slightly and maintained a relatively stable volume throughout August, until finally decreasing in visitation at the end of August. There is a noticeable increase in the visitation of these vehicles at the end of August. While this does describe the general trend for vehicles throughout the season, visitation on individual days was highly variable.

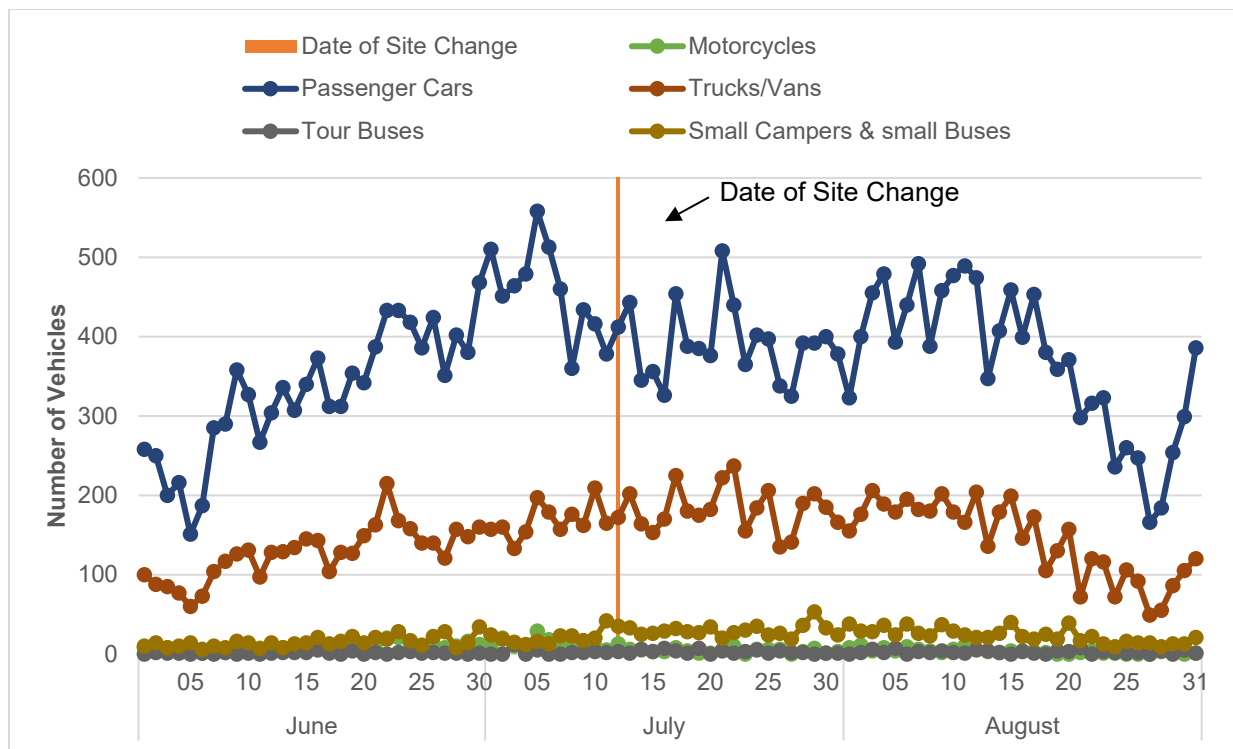


Figure 7. Daily vehicle counts for each vehicle class.

Visitation patterns for Motorcycles, large campers/small buses, and tour buses are notably different from the other vehicle classes (Figure 8). Tour buses appeared to generally come in groups rather than individually, as only 12 of the 95 days, or 13% of days, had a single tour bus. Motorcycle traffic was highly variable across the season, with the highest count occurring on July 5 and then steeply declining after that point. The volume pattern for large campers/small buses tended to steadily increase through the season into the end of August before beginning to decline. The peak day for this vehicle class occurred on July 29 with a count of 53 vehicles.

There is a noticeable break in the data occurring after the classifier was moved from Site 1 to Site 2. This was due to an error caused by the placement of the road tubes. Long vehicles were not crossing the road tubes perpendicularly at Site 1 which caused some of them to be misclassified as Motorcycles, although some were incorrectly placed into Classes 6–13 as well. This error accounts for the higher Motorcycle counts in Site 1 compared to Site 2, and the lower counts for large campers/small buses and tour buses.

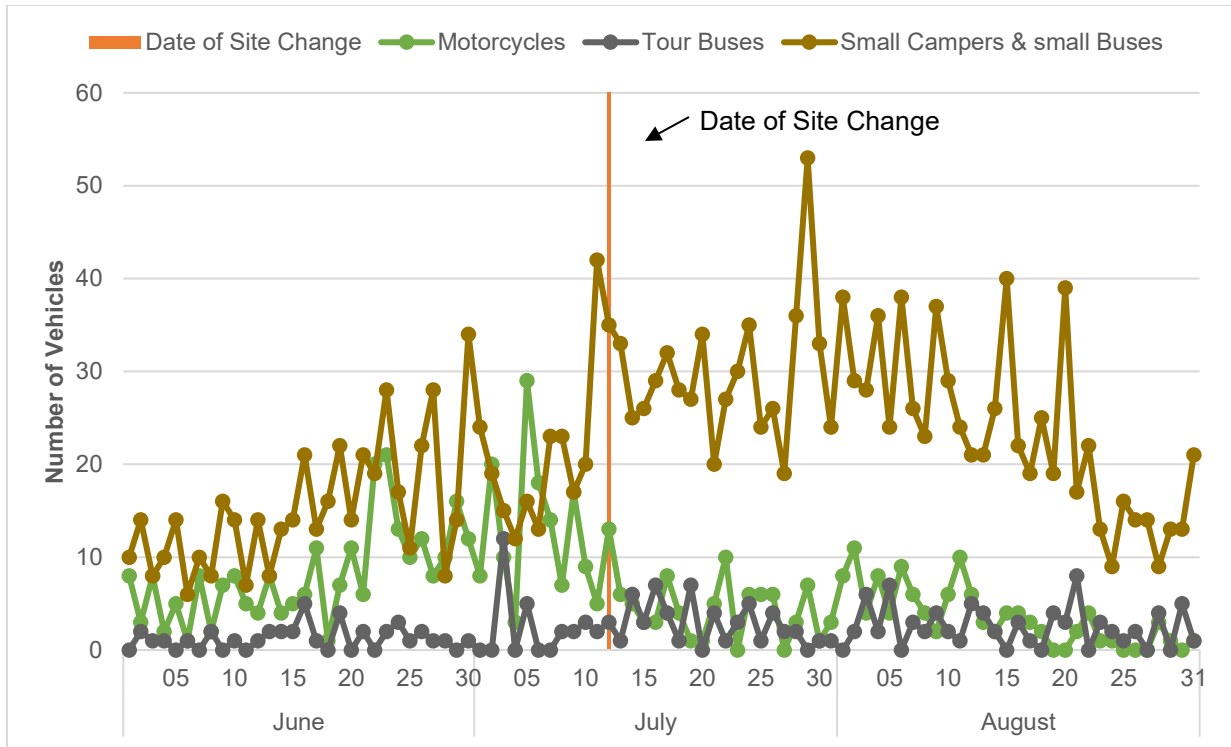


Figure 8. Daily Vehicle Counts for Class 1, 4, & 5 Vehicles.

People-Per-Vehicle Survey

From May 29 to August 31, 22 people-per-vehicle surveys were conducted. A total of 2,655 vehicles were surveyed during that time. Of these, 27 were Motorcycles, 1719 were passenger cars, 774 were trucks/vans, 25 were tour buses, and 110 were large campers/small buses. (Table 6). To obtain the PPV from this data, the total number of people observed on board each vehicle was divided by the total number of vehicles in each class. This expressed by the formula below.

$$PPV = \frac{\sum Passengers_{class}}{\sum Vehicles_{class}}$$

Results from the people-per-vehicle counts showed an average PPV of 3.5 for all vehicles. Motorcycles averaged 1.3 PPV, passenger cars carried 2.8 people on average, trucks/vans had a PPV of 4.1, tour buses averaged 26.8 passengers, and large campers/small buses averaged 6.6 people on board (Table 6).

Table 6. Summary of PPV for all vehicle classes observed.

Vehicle Class	Number of Vehicles	Number of People	Average PPV
Motorcycles	27	36	1.3
Passenger Cars	1719	4776	2.8
Trucks/Vans	773	3094	4.0
Tour Buses	25	670	26.8
Large Campers/Small Buses	111	774	7.0
Total	2655	9350	3.5

The average PPV for vehicles tended to increase as the size of the vehicle increased, corresponding to greater carrying capacity. There are some exceptions to this trend, however. For example, RVs categorized as Class 5 vehicles tended to have fewer passengers than RVs placed into Class 3. Although the average PPV for tour buses was 26.8, the range for these vehicles was much higher. tour buses were observed to have as many as 50 passengers on board and as few as 6 people.

Calculating Visitation

Another objective of this project was to update KEFJs visitation estimates in the Exit Glacier Area. Currently, KEFJ uses a vehicle counter to track vehicle volume and a single PPV factor for all vehicle types. Vehicle counters only record vehicle volume and cannot distinguish between vehicle classes. When using vehicle counters, the variation in the number of visitors arriving to the park by different vehicle classes cannot be calculated, and therefore yields results that, while still useful, are less precise than the classifier.

With the data the classifier can gather, there are two options for calculating visitation. The first method, or the generalized method, is the same as what KEFJ is using currently with an updated PPV multiplier. The total sum of vehicles can be multiplied by a single PPV factor. The generalized method is represented by the formula below, where $\overline{PPV}$ represents the average PPV for all observed vehicles.

$$Visitation = \Sigma \text{Vehicles} * \overline{PPV}$$

The second method for calculating visitation, named the differentiated method, is slightly more complex but can help to capture the nuances of passenger occupancy between different vehicle classes. In the differentiated method, the number of visitors is calculated by using a different PPV factor for each vehicle class and then adding them all together to obtain total visitation. This is represented by the formula below, where V_C is the vehicle volume for a specific class, and $\overline{PPV}_C$ is the average PPV for a specific class.

$$Visitation = \sum_{C=1}^{13} (V_C * \overline{PPV}_C)$$

It is illustrative to compare visitation estimates using the different methods (Figure 9). The generalized method uses the new single PPV multiplier of 3.5 times vehicle volume data. The KEFJ Method, which is the generalized method, multiplies the old PPV of 2.9 times vehicle volume data. The differentiated method uses a different PPV factor for each vehicle class and totals them together. Each of these methods calculates visitation using the number of vehicles detected in the Exit Glacier Area from June–August 2019.

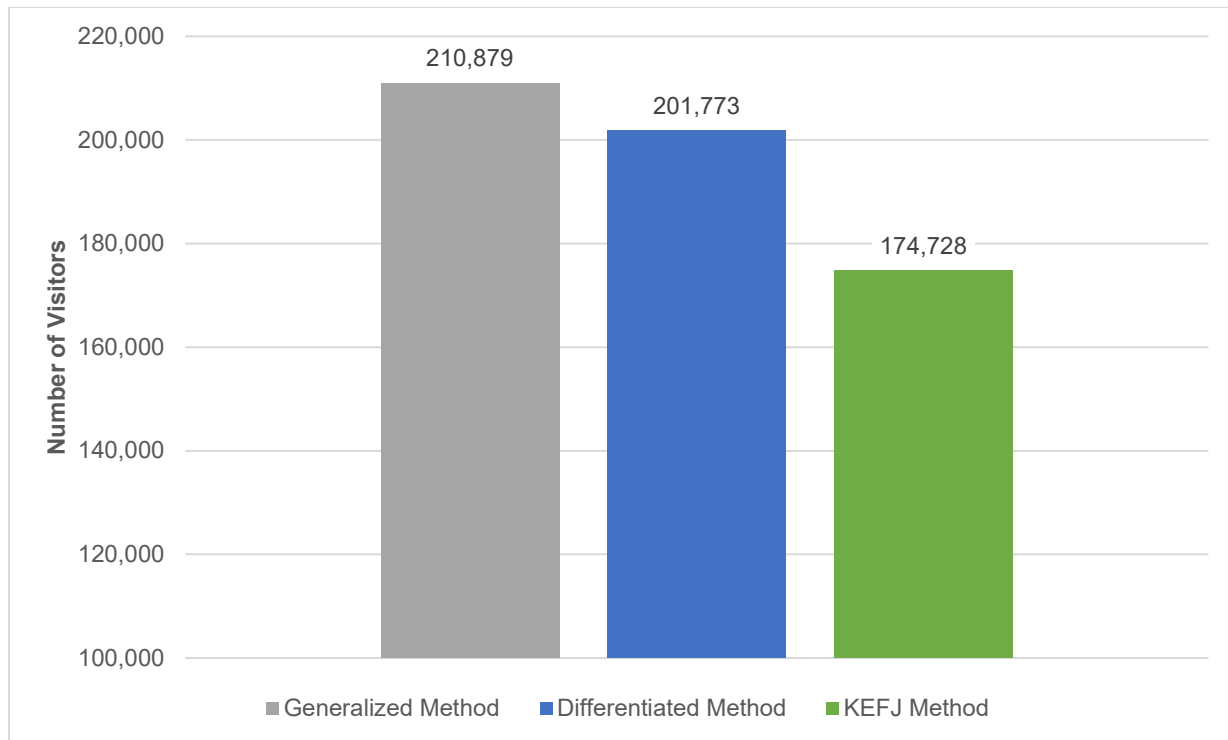


Figure 9. Visitation estimates between three calculation methods.

The results from this study demonstrate that the number of visitors in a vehicle can vary significantly between vehicle classes and that employing individual PPV factors for each class of vehicle may provide a more accurate representation of visitation. For example, a shift in the types of vehicles visitors use to access the park, say an increase in shuttle buses, may include an increase in visitation but no change, or even a decrease in the number of vehicles. A PPV factor across all vehicles would not capture this change in visitor numbers.

Data from this study shows noticeable variations in visitation and daily traffic counts between the three months surveyed (Figure 5, Figure 9). June, July, and August account for the majority of visitors coming to the Exit Glacier Area. June and August have less visitation than July, as each of these months contain days which are part of the shoulder season for KEFJ. In June, visitation begins to increase throughout the month, while visitation tapers off towards the end of August. As July occurs during the middle of the summer season, it has the highest number of visitors.

Discussion

Distinguishing Commercial and Non-commercial Vehicles

One of the primary objectives for this study was to test if the Omega X3 would be able to distinguish between commercial and non-commercial vehicles. This was of interest because it had been previously observed that commercial vehicles, such as small buses and vans carrying guided groups, were bringing in more visitors per vehicle than non-commercial vehicles of the same type. Being able to document this information would help refine visitor statistics and provide more insight into the dynamics of visitation in the Exit Glacier Area.

Distinguishing between commercial and non-commercial vehicles is beyond the ability of the classifier. This is because commercial and non-commercial vehicles can be of similar dimensions despite their difference in use. Tour buses are an exception to this, however, as no non-commercial tour buses vehicles were observed at Exit Glacier during the entire 2019 study period. Although not all tour buses detected by the classifier were observed in person, it is unlikely that any private vehicles of similar dimensions entered the Exit Glacier Area.

To illustrate the difficulty of identifying commercial and non-commercial vehicles, compare the two vans pictured below (Figure 10). Both vehicles are categorized as a truck/camper van. The van on the left is a non-commercial vehicle which carried only two passengers, while the vehicle on the right is a commercial vehicle that brought between 1 and 10 visitors to Exit Glacier multiple times per day. As can be seen, these vehicles are very similar in construction, size, and length, yet the type of use associated with each vehicle is very different. To the Omega X3, these vehicles are both treated the same and are binned as Class 3 in the dataset. Without observational data, it is impossible to distinguish these vehicles using the classifier.



Figure 10. Non-commercial and commercial Class 3 vehicles at Exit Glacier parking lot (NPS/Tyler Balstad).

Of the 179 commercial vehicles observed in the Exit Glacier parking lot, 129 belonged to trucks/vans, followed by 25 tour buses and 17 in large campers/small buses. Those categorized as trucks/vans and large campers/small buses could not be distinguished from other non-commercial vehicles in the data without having observational notes. As no non-commercial tour buses vehicles were seen during the study period, it was assumed that all those detected by the classifier were commercial.

Being unable to distinguish commercial and non-commercial vehicle use in the Exit Glacier Area presents a gap in KEFJ's visitor statistics. While the commercial vehicles observed during this study represented 6.7% (179/2,655) of the total vehicle volume, they accounted for 21.6% (2,022/7,328) of the visitors. The need to have a clearer representation of commercial and non-commercial use must be carefully weighed. More precise numbers can lead to greater confidence when making management decisions, but the cost of acquiring this data requires a large time commitment as it can currently only be obtained through in-person observation. Alternate methods for acquiring this information should be considered by park management.

Calculating Visitation

Utilizing the Omega X3 to calculate the visitation to the Exit Glacier Area can be accomplished using either the generalized or differentiated method previously discussed (Figure 9). These two methods differ in terms of the precision of their results and the associated workload. In terms of visitation estimates, these two methods differ by 4.41%. This is not a large difference, and the increased workload to use the differentiated method, which provides a more accurate estimate, may not be worth accounting for this small difference. The generalized method involves a simpler workload, as it involves applying a single PPV factor to total traffic volume. This is the same method currently used for calculating visitation by KEFJ, but with an updated PPV multiplier, and would be easier to integrate into existing park visitor statistics database. The visitation estimate using the generalized method, however, is less precise.

The differentiated method provides finer visitation detail useful for park management, but it requires an increased data collection workload and more complex data management. The databases KEFJ uses to manage and report its visitor statistics and the NPS national statistics database, would need to be modified to accommodate the Omega X3 data. This would require collaboration between the Resource Management and Administration team at KEFJ and the National Park Service Visitor Use Statistics Coordinator. This increased workload could be worth the extra effort to provide a visitor estimate that can immediately reflect changes in modes of visitor access and the associated visitation numbers.

Changes in Vehicle Volume and Class Composition

The classifier can be used to interpret long term changes in vehicle volume and class composition. Long term analysis of vehicle classes will allow park management and staff to understand and respond to changes in visitor access modes and changes visitation. Additionally, vehicle numbers and class composition information can be used to assess the need for road maintenance, to improve the safety of the parking lot, and to make data-driven decisions about visitor access to the Exit Glacier Area.

No previous studies have been conducted in KEFJ to assess vehicle classification in the Exit Glacier Area. By continuing to use the Omega X3 vehicle classifier, KEFJ will have a consistent classification scheme for future studies. Uniform vehicle classification, using data from this year as a baseline, would allow for meaningful comparisons to be made in the future.

Timing of Use

Understanding the timing of visitor use at Exit Glacier is critical for park management functions including staffing, scheduling ranger programs, patrolling trails, and managing traffic. Data from the classifier can be used to produce the Average Hourly Traffic (AHT), Average Daily Traffic (ADT), and give Daily Vehicle Volume (DVV), all of which help identify busiest times of day, week, month, and season. Additionally, these data can be used to estimate when the parking lot will experience congestion, that impacts visitor experience and staff resources.

There are both notable differences and similarities in the timing of visitation at Exit Glacier from June through August. For all three months, visitation increased more rapidly prior to noon than the rate at which it decreased after noon. This fact contributes to the parking lot filling up early in the day and remaining full until the evening. In June, July, and August visitation peaked daily between 11:00 a.m. – 11:59 a.m.

An effort was made to estimate the times at which the parking lot's capacity is exceeded and by how many vehicles (Figure 11). The parking lot capacity at Exit Glacier was determined to be 116 spaces. This number is a sum of all available parking spaces, including spaces in the parking lots and designated overflow spaces. This does not include sites where vehicles were observed parking along the edges of the parking lot and roadways. The lot capacity does not treat designated RV parking spaces differently than those designated for passenger vehicles, although passenger cars have been observed double parking in a single RV space. This fact makes the theoretical capacity for the lot greater than the designed capacity. Therefore, while establishing the capacity at 116 spaces may not capture every nuance of what occurs within the Exit Glacier parking lot, it provides the most reasonable, reliable, and quantifiable benchmark for assessing lot use. Vehicles generally remained at the parking lot for around 2 hours, and by using this estimate with the AHT, the number of vehicles parked in the parking lot was estimated.

The formula for calculating the number of parked vehicles for a given hour at Exit Glacier is given below. In this formula, N is the number of vehicles counted by the classifier for a particular hour, t is the hour, and AHT is the average hourly traffic rate. This formula sums the AHT for a particular hour with the AHT from the two previous hours, as it is assumed that vehicles are typically staying in the parking lot for this length of time. This 2-hour stay is a qualitative estimate based upon my field experience but should be tested before the park relies on it to make important decisions.

$$N = AHT_t + AHT_{t-1} + AHT_{t-2}$$

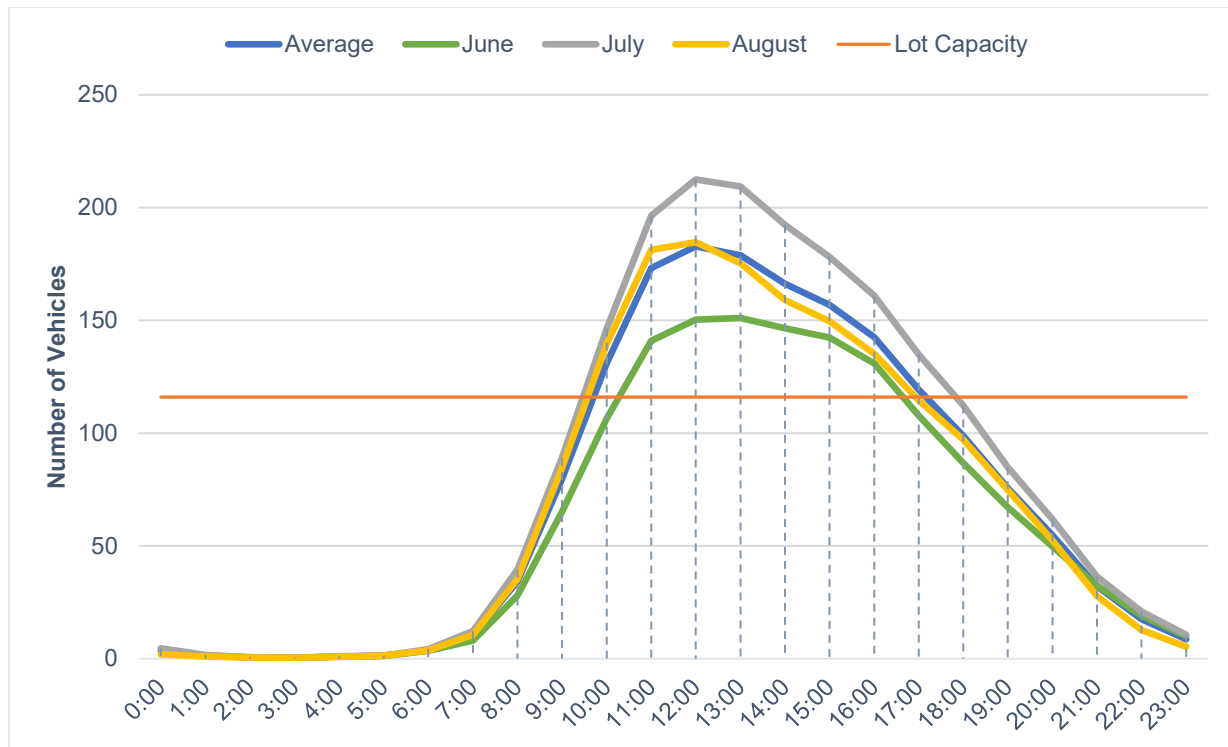


Figure 11. Chart displaying parking lot capacity using AHT and a two-hour visitation length per vehicle.

Figure 11 shows that on an average day from June through August, the Exit Glacier parking lot will exceed its capacity. By having a best estimate of the parking lot’s functioning capacity, a realistic and quantitative assessment of use for parking lot management and planning can be completed.

Volume and Classification Accuracy Factors

The best index for assessing the classifier’s accuracy are the volume accuracy factor (VAF) and the classification accuracy factor (CAF). The classifier’s VAF was found to be 99.5% and the CAF was found to be 94.8%. This means that the classifier registered 99.5% of the total number of observed vehicles entering the Exit Glacier Area, and of these it placed 94.8% into the correct vehicle class. From these two indexes, it is clear the classifier is highly accurate, yet not infallible.

Companies that sell classifiers often claim accuracy rates of 99%, although few studies have been undertaken to test the validity of this claim. Specific investigations into the accuracy of devices that use pneumatic road tubes show rates of error that are closer to 10 percent (McGowen 2011). For the vehicles entering the Exit Glacier Area, the Omega X3 provides reliable and precise data.

Slow Vehicle Speeds

Errors in classifier data occurred when vehicles drove too slowly over the road tubes. While the classifier can detect speeds as low as 5 mph, this is the low end of its range. Fewer errors result when vehicles drive at least 7 miles per hour over the road tubes (Diamond, 2019).

Slow moving vehicles can generate air signals that are too weak to be detected by the classifier’s transducers. Typically, in this case vehicles will register as a Class 0 in the database with a timestamp

but will not include any speed or vehicle length data, making classification of the vehicle impossible. Rarely, vehicles crossing the road tubes will not be recorded at all by the classifier. These are errors that affect the VAF, as there is too little vehicle data to be counted towards the total record.

The classification accuracy can also be affected by slow moving vehicles because the timing between the front and rear axle is calculated as being longer than it actually is. This skews the CAF as the vehicle is added to the total volume record but is incorrectly classified.

There were several common scenarios observed in the Exit Glacier Area that contributed to vehicles travelling slowly. The layout of the inbound road and the posted speed of 15 mph occasionally induces drivers to travel much slower than necessary. This could also be influenced by visitors' unfamiliarity with the area and wanting to travel slowly to read traffic signs.

A second major contributor to vehicles moving slowly is traffic congestion and full parking lots. On days of high visitation, vehicles became bottlenecked along the road where the classifier is installed. Typically, the higher concentration of vehicles at a single time along the road results in slower vehicle speeds, as drivers reduce their speed due to the increased potential hazard of collision. Lack of spaces in the parking lot can contribute to congestion and slow speeds, as drivers loop around the parking lot several times and drive more slowly while searching for somewhere to park. These types of situations can decrease the accuracy of the classifier, as lower vehicle speeds increase the likelihood of undetected or misclassified vehicles.

Angle of Travel

A vehicle's angle of travel is the angle between its axles and the road tubes. Ideally, vehicles should cross the road tubes at exactly 90 degrees to ensure the tires on each axle strike the road tubes simultaneously. Proper installation of the road tubes perpendicular to the road is crucial, otherwise this results in both classification and volume errors.

Even when properly installed, however, some vehicles still travel at an angle to the road tubes. This occurs when vehicles try to avoid hazards on the road, such as improperly parked vehicles on the road edge or wildlife. Additionally, inattention from drivers can cause them to veer along the road and cross the road tubes at a skewed angle. A final contributing factor that was observed was the design of the road itself. The inbound road to the parking lot is not perfectly straight, but instead is slightly curved. Vehicles will occasionally begin to change their angle of travel in anticipation of this curvature. This is particularly true for longer vehicles, such as tour buses, as they have a larger turning radius and thus need to shift their angle of travel sooner than smaller vehicles.

Overcounting of Vehicles

Overcounting of vehicles can occur for a variety of reasons and can affect conclusions made using the classifier data. Overcounting is not an issue with the Omega X3 per se but is the result of vehicle driving patterns in the Exit Glacier Area. It is impossible to detect if a vehicle has already crossed the road tubes, so individual vehicles can be counted multiple times if they drive over the road tubes more than once.

One recurrent source of over counting that occurred in the classifier data was caused by vehicles that crossed the road tubes multiple times as they circled the parking lot during a single visit. This occurred when the parking lot was full and visitors were looking for a parking space to open up, or when commercial drivers dropped off passengers in front of the Nature Center, parked in the parking lot, and then picked up their passengers in front of the Nature Center at the end of their visit (this can equal multiple counts for one vehicle).

Currently, demand for parking spaces at the Exit Glacier parking lot exceeds the number of spaces available during busy times of the day. Parking lot crowding occurred most frequently from the end of June through the middle of August, particularly during peak visitation hours from 10 a.m. – 3 p.m. Once the parking lot and overflow parking capacity were reached, many vehicles drove through the parking lot multiple times in search of an empty space. Each time vehicles crossed over the road tubes, they added to the total number of recorded vehicles. This created a higher visitation count because a PPV factor was applied to these vehicles each time they crossed the road tubes. At present, there is no way to account for this source of error because the classifier cannot distinguish between novel or repeat vehicles.



Figure 12. Example of vehicles parking in overflow sites in the parking lot. Vehicles on the right side are parked in designated overflow sites, while vehicles on the left are parking on the road, which can cause safety issues (NPS/ Tyler Balstad).

Overcounting can also occur when vehicles pick up passengers in front of the Exit Glacier Nature Center. Some vehicles have passengers disembark and embark at the parking lot, which results in the vehicle only being counted a single time. Other drivers, particularly certain chauffeurs of commercial vehicles, will unload passengers in front of the Nature Center, park their vehicle in the parking lot, and then circle around to pick up their passengers in front of the Nature Center. This causes them to cross the road tubes twice and results in overcounting of the number of vehicles and passengers. Mitigating this error would likely be very difficult, as it has no single cause. Some drivers will pick up their passengers in front of the Nature Center because of personal preference, while others do so when parking is limited. Most vehicles do not follow this driving pattern, and the overall error caused by these situations is small.

A final source of overcounting occurs when KEFJ staff drive over the road tubes. The parking lot used by KEFJ staff at Exit Glacier is closed to the public but is accessed by the same road as visitors entering the area. Therefore, staff and visitors both are counted by the vehicle classifier. This represents a negligible amount of error, as the number of park staff vehicles compared to visitors is exceedingly small. From observations in 2019, park staff accounted for less than one percent of vehicle traffic at Exit Glacier.

Passenger Car and Truck/Camper Van Misclassification

Although the Classification Accuracy Factor for the classifier shows that it is quite accurate at classifying vehicles, it is worth exploring the specific errors in misclassification. The most common error is passenger cars being classified as trucks/vans, and vice versa (Table 5). These two types of error account for 47.5% (58 / 122) of all misclassifications.

The frequency of these errors is likely due to several factors. One is that these vehicles represented about 93% of all vehicles coming to Exit Glacier in 2019 (Figure 6, Table 3). Since the Omega X3 will always have a certain degree of error, it is to be expected that these vehicles would have the highest rate of recorded error as they represent the highest percentage of vehicle volume.

A second factor is that these misclassified vehicles were often on the large or short end of their vehicle class axle lengths. Using vehicle records from the classifier database, I was able to compare the axle spacing for all the vehicles I observed during this study. The average length for all passenger cars was 9.19 feet, but the average length of passenger cars misclassified as a truck/camper van was 10.66 feet (Table 7). The average length for trucks/vans was 12.45 feet, while the average length for trucks/vans misclassified as passenger cars was 11.23 feet. The difference in length between the average passenger car and truck/camper van was 3 feet 3 inches (12.45'–9.19'), whereas passenger cars and trucks/vans mistaken for each other were on average only 7 inches (11.23'–10.66') different in length. This small difference in length appears to approach the classifier's limitations of precision at determining vehicle length.

Table 7. Average lengths of Passenger Cars and Trucks/Vans.

Class	Average Length (ft)	Average Misclassified Length (ft)
Passenger Cars	9.19	10.66
Trucks/Vans	12.45	11.23

Although there is no simple way to reconcile these various errors, the Omega X3 still provides data that produce useful representations of the vehicle classes, traffic patterns, and visitor use in the Exit Glacier Area.

Environmental Conditions Effecting Visitation in 2019

Seward is located within a temperate rainforest, on average receiving about 73 inches of rain each year (NOAA, 2019), and heavy rainfall can reduce the number of visitors to the Exit Glacier Area. In 2019, precipitation was well below the average for each month of this study. The average monthly precipitation in June is 2.42 inches, but only 0.20 inches fell that month. July receives an average of 2.80 inches of rainfall, but only 2.01 inches were recorded. Lastly, the average precipitation for August is 5.61 inches, and only 0.32 inches were observed in that month. These dry and mostly sunny conditions may have led to an increase in the number of visitors at the Exit Glacier Area as there were fewer rainy days to deter visitors.

Another climactic factor which likely affected visitations was the number of smoky days recorded in Seward in 2019. The Swan Lake Fire in the Kenai National Wildlife Refuge and other small fires in the interior of Alaska contributed to high levels of smoke and particulate matter in Seward and the Exit Glacier Area. A PurpleAir sensor located in Seward recorded the concentration in $\mu\text{g}/\text{m}^3$ of fine particulates measuring less than 2.5 microns (PM 2.5) released by the Swan Lake Fire. As this sensor is only 12 miles from the Exit Glacier Area, the data collected at this site can provide an example of how poor the air quality might have been in the Exit Glacier Area at the time.

While many days of the summer had at least some concentration of PM 2.5, the month of August had some remarkably high levels (PurpleAir, 2020). From August 15 to August 29 PM 2.5 levels became dangerously high in both Seward and in the Exit Glacier Area. After August 29, levels returned to safer levels throughout September (Figure 13). There is saddle in visitation corresponding to the days with higher PM 2.5 concentration (Figure 6). The colored bands in Figure 13 correspond to the EPA's health concern categories, listed in Table 8.

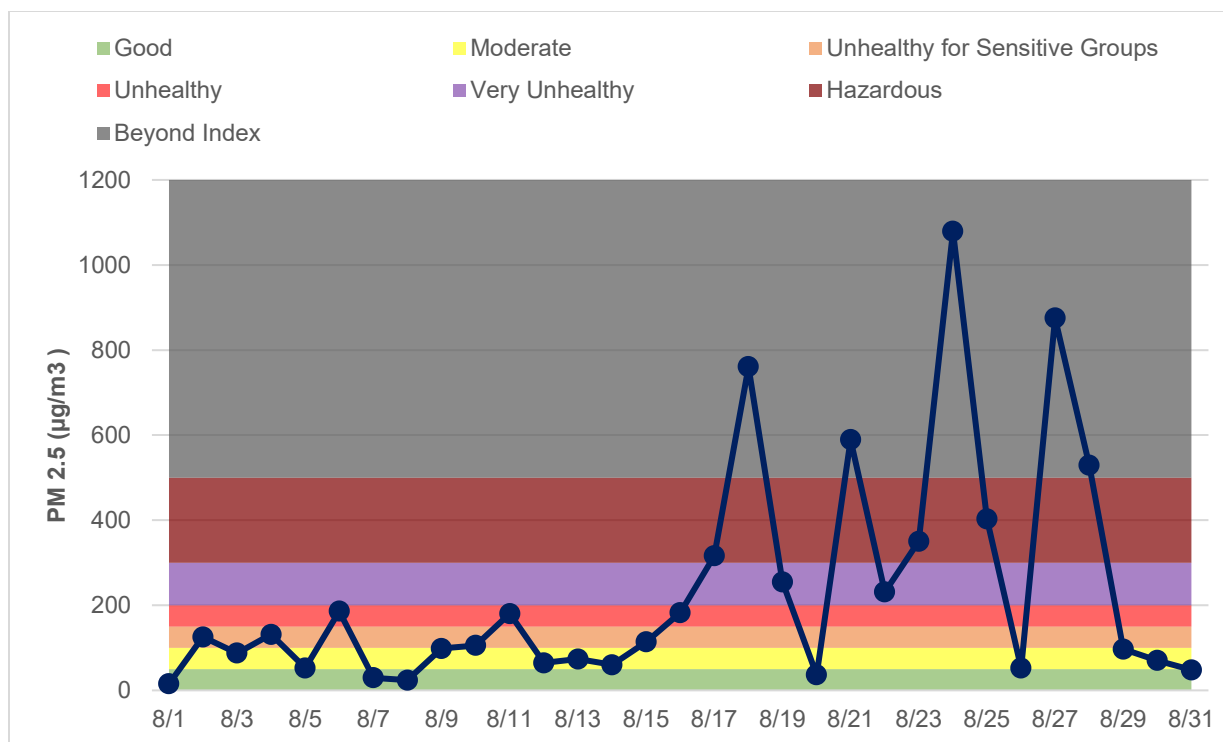


Figure 13. Fine Particulate (PM 2.5) concentrations in August 2019 for Seward, Alaska.

Table 8. Health concern levels based on PM 2.5 concentration.

Air Quality Index Levels of Health Concern	PM 2.5 (µg/m³)	Meaning	Color Band
Good	0 to 50 (Green)	Air quality is considered satisfactory, and air pollution poses little or no risk.	Green
Moderate	51 to 100	Air quality is acceptable; however for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Yellow
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Orange
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.	Red
Very Unhealthy	201 to 250	Health alert: everyone may experience more serious health effects.	Purple
Hazardous	251 to 350	Health warnings of emergency conditions. The entire population is more likely to be affected.	Brown
Beyond Index	> 500	Values above 500 are considered Beyond the AQI. Follow recommendations for the Hazardous category.	Gray

Between August 15 and August 29, only 4 days had PM 2.5 concentration that were not likely to affect the general public. The remaining 11 days had PM 2.5 concentrations high enough to warrant health alerts for the general public, and 5 days exceeded the maximum level for the air quality index.

Many air quality advisories were issued during the study period due to high concentrations of smoke particulates in the air (ADEC, 2019), encouraging individuals to stay inside in well-ventilated areas and avoid physical strain. These conditions likely affected visitation during the study period, as the smoke limited views of Exit Glacier, and the poor air quality affected all members of the population.

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Appendix A

This appendix provides specific examples of different vehicles observed at Exit Glacier and the classes they were placed in. The intent is to provide clearer examples of the vehicle class for common types of vehicles and to illustrate the diversity seen within certain vehicle classes.

Class 1 	Class 4 
Class 2     	Class 5  
Class 3     	 

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