A Report from the University of Vermont Transportation Research Center

Passenger Vehicle Idling in Vermont: Year 1 Report

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Disclaimer

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1 Introduction

The transportation sector in Vermont is the largest user of energy and the largest source of greenhouse gas (GHG) emissions in the state (USEPA, 2009; VTrans, 2008). The combination of rural land use patterns and limited public transit make residents heavily reliant on passenger-cars and result in long single-occupant vehicle trips in Vermont. The large percentage of GHG emissions generated by the transportation sector makes it an important target within the state for emissions-reduction efforts (VDPS, 2011).

There are a number of driver behavior-based strategies that have been used to reduce GHG emissions by drivers. These strategies together are often referred to as "eco-driving" and they include reducing idling, reducing rapid acceleration and deceleration, reducing speed on highways, keeping tires inflated, keeping the engine tuned-up, and removing excess cargo. As of 2012, 21 states (including Vermont) have statewide idling laws that cover at least trucks, with five states (Connecticut, Hawaii, Maryland, Massachusetts, and Virginia) including all motor vehicles in their idling restrictions (IFVT, 2012).

In an effort to reduce energy use and GHG emissions, and to ensure the health of Vermont's schoolchildren, the state presently has a law prohibiting the idling of school busses for more than 5 minutes (VDOE, 2007), while its largest city, Burlington, has a law prohibiting idling of any vehicle for more than 3 minutes (BVCO, 2012). These laws reflect a growing recognition that idling is a wasteful activity and not in keeping with Vermonters' sense of efficiency, environmentalism and frugality. The impacts of idling on vehicle drivers include poor air quality for them and their passengers, increased engine wear, and increased fuel use. Idling for 1 hour can burn up to 0.5 gallons of gasoline (Taylor and Eng, 2003), and emit 19.4 lbs of CO_2 (USEPA, 2005). Reducing fossil fuel consumption is important not only in terms of emissions but also in terms of personal and state economics. At least 80 cents of each dollar spent on gas in Vermont leaves the state economy (USEIA, 2010; Tax Foundation, 2010).

While real-time information on idling behavior of long-haul trucks, motor coaches and buses are readily available, similar data on idling behavior of passenger vehicles (PVs), including light-duty cars and trucks, is scarce. A series of studies by Natural Resources Canada found that drivers self-reported only about 8 minutes of idling behavior per day, but were observed idling between 1.5 and 3 minutes per stop (NRC, 1998; NRC, 2001). Using an average number of stops per day of about 5 (Aultman-Hall et al., 2010), it is possible that self-reports of normal idling time (8 minutes per day) may be underestimating true normal idling time by up as much as 7 minutes per day. This finding suggests that direct vehicle instrumentation may be necessary to accurately assess the prevalence of idling. A study by members of the Vermont TRC team of over 250 PVs in the Lexington, Kentucky region showed the time a vehicle was idle to be about 24% of total vehicle operating time (Aultman-Hall et. al., 2010). Others have found that vehicles use about 30 percent of their fuel while idle (Jurgen, 1995). The National Household Travel Survey (NHTS) routinely finds that drivers travel for about 60 minutes a day (Hu and Reuscher, 2004), but a study by the USEPA has shown that light-duty-vehicle owners tend to have their cars running for about 80 minutes a day (USEPA, 2010).

The difference between the operating time and the actual travelling time comes to about 25%. Eliminating this idling, then, could save about 0.13 gallons of fuel per day per driver in Vermont, or a total of over $63 million, 22.5 million gallons of fuel, and 840 million pounds of CO_2 emissions per year.

A better understanding of PV idling behavior in Vermont will help policymakers develop targeted strategies to reduce this behavior. There are presently no published surveys on the reasons behind idling behavior in Vermont. Aside from the study by Natural Resources Canada, there is little measured data on the effectiveness of the strategies that will reduce idling by PVs, in Vermont or elsewhere. The primary goal of this project is to provide this improved understanding, including the variations in PV idling behavior in urban and rural settings, between demographic groups, and by season.

From a policy perspective, it is important to be able to distinguish between discretionary idling events, which are directly controlled by individual drivers, and non-discretionary idling caused by conditions such as congestion and traffic control devices, that are external to the driver's control, as different interventions may be required to reduce the duration and frequency of each. Discretionary idling events, for example, could be reduced with additional anti-idling ordinances (IFVT 2012) and driver education programs such as eco-driving (Barkenbus 2010). Reducing non-discretionary idling, in contrast, may depend on factors such as retiming signals, reducing congestion or improving vehicle-routing. Since few previous studies have attempted to make this distinction, new definitions of, and methods for, identifying discretionary and non-discretionary idling were developed within this project.

In this study, reduction of time a vehicle is idling in traffic on the roads (non-discretionary idling) was not considered as a feasible strategy for fuel and emissions reductions for two reasons. The first is that the most ambitious anti-idling recommendations assume that the vehicle operator has no control over this type of idling behavior (IFVT, 2012). The second reason is that some of the most recent studies from the international research community have begun to suggest that efforts to restrict idling in traffic will compromise the safety of the vehicle operator and passengers (Jou et. al., 2011). The time a vehicle spends idling while stationary in traffic was categorically distinguished as non-discretionary idling for the purposes of this project. Idling out of traffic occurs primarily at trip-starts or trip-ends. Trip-start idling occurs after the engine has been started (key-on) and before the vehicle moves for the first time. Trip-end idling events occur once a vehicle has arrived at its destination and before the engine has been turned off (key-off). In the case of trip tours or chaining, trip-end idling events can occur at intermediate destinations and thus multiple trip-end idling events may occur in an operating-period between key-on and key-off. The duration of trip-start or trip-end idling, while it cannot be completely eliminated, is almost entirely controlled by the driver and thus will be categorically considered as discretionary idling.

Distinguishing trip ends in in-vehicle GPS data streams is a well-recognized challenge. While times of zero velocity can be easily identified, determining whether these time periods are associated with traffic control and congestion or an intermediate trip end requires use of additional logic and data processing. Other research has shown the importance of heading-change in the identification of trip starts, trip ends, and discretionary idling (Stopher et. al., 2003; Aultman-Hall et. al., 2005). In-vehicle GPS data loggers often omit times when the vehicle is stopped from saved records to conserve data storage on the device. This omission as well as the presence of true zero-velocity time periods while traveling complicates the identification of discrete trips, often requiring heuristic processing (Aultman-Hall et. al., 2005). These processing steps include identification of instances (shown in Figure 1) where:

- The vehicle traverses a single point twice in a relatively short period of time, with a heading change of approximately 180 degrees; and
- The vehicle leaves the roadway.

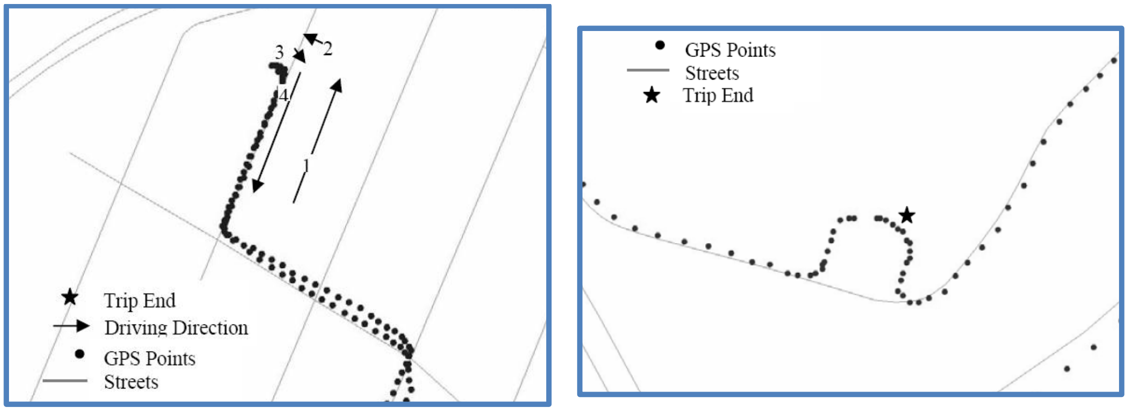


Figure 1 Steps to Identify Discrete Trips from GPS Data (from Aultman-Hall et. al., 2005)

In travel demand analysis, a discrete trip is distinguished by a specific purpose or stop when the driver or passenger undertakes an activity. Especially, when the purpose or activity is of a short duration, the engine might be left on with the vehicle idle at these intermediate trip ends. The critical distinction is between the end of one trip and the beginning of another. Making that type of distinction within the GPS data stream is not difficult for trip ends where the key-on and key-off markers can be used. However, the identification of the ends of sub-trips between key-on and key-off, where the vehicle has left the roadway to park and idles before starting to move again, are critical to include when distinguishing between discretionary and non-discretionary idling. Therefore, an adapted method was developed utilizing heading change and was used in this project to distinguish trips ends and thus between discretionary and non-discretionary idling.

This report includes the results and description of Year 1 of this project. While the overall goal of the project is to better understand the potential for reductions in fuel use and emissions that could result from a reduction or elimination of discretionary idling in Vermont, the Year 1 study was primarily intended to pilot-test the in-vehicle equipment and data collection as well as a comprehensive analysis method for assessing driver idling behavior for Vermont drivers.

The scope of Year 1 included the collection and analysis of second-by-second data on the driving behavior of 20 randomly selected drivers in Vermont, for a pilot-scale application of new methods to distinguish between discretionary and non-discretionary idling by PVs in Vermont. By collecting data in summer and winter, the project team developed an initial understanding of the seasonal differences in idling behavior during this project phase. A more in-depth understanding of the spatial and demographic differences in idling behavior throughout the state is expected to follow in Year 2, along with an estimate of total fuel used and carbon emitted from discretionary idling by Vermont drivers.

Section 2 of this report includes a description of the testing and selection of equipment for the study, along with the approach to securing institutional review board (IRB) approval for research involving human subjects and recruiting volunteer drivers. Recruitment included an-on-line survey. Section 3 describes the process used for data collection, including instrumentation of the volunteers' vehicles, as well as downloading and tabulating their data. Section 4 contains a description of the methods used to analyze the data and the results of the analysis. Section 5 contains the conclusions of the study, along with an outline of avenues for future research.

2 Equipment Selection and Volunteer Recruitment

2.1 Equipment Selection

For this study, the subjects' vehicles had to be equipped with device(s) capable of recording the vehicles' position and speed whenever the engine was operating. Implicitly, then, it was necessary for the device(s) to respond to the key ignition, and begin logging second-by-second data immediately. The research team began the equipment selection process by evaluating GPS devices, since they are routinely used to record both vehicle speed and position on a second-by-second basis.

Table 1 provides a list of the portable GPS devices evaluated along with comments on their suitability for this project. Each of these devices is designed to be installed in a motor vehicle to record its speed and position over a period of time. Most of these devices are designed for fleet monitoring applications, where the owner of large vehicle fleet can track the movements of each of its vehicles to ensure quality performance. Other devices are designed for parents to monitor the driving behavior of their teens.

Table 1 Portable GPS Devices Evaluated

Device	Manufacturer	Comments
GO5	GeoTab	Active GPS system. Excellent features but requires service contract. Cost prohibitive for short term study.
GO4v2	GeoTab	Passive system. Must be hardwired into vehicle. Not suitable for quick installation in and removal from volunteer vehicles.
AT-X5	DynaTrack	Active GPS. Requires service contract. Must be hardwired into vehicle.
BT-Q1000X*	QStarz	Passive GPS recorder. Cumbersome download utility.
3100	LandSeaAir	Only records once per hour when the vehicle is not in motion.
GeoLogger*	GeoStats	Passive GPS recorder. No longer sold.
TrackStickPro	Telespatial Systems	Only records every 5 seconds. Insufficient memory for study period.
LiveWire		Active GPS. Must be hardwired into vehicle.

Device	Manufacturer	Comments
TravelEyes2	Advanced Tracking Tech.	Passive GPS. Does not record when the vehicle is not in motion.
	Network Fleet	Active GPS System. Requires service contract. Only records at two-minute intervals.

*Purchased and tested in vehicle.

Infrequent data logging, insufficient memory, and slow satellite-acquisition precluded most of the devices from being used in our study. Many of the devices have automatic power-saving features that reduce their data recording and logging when the vehicle is not in motion. This feature would have prevented the logging of data at the moments that are most crucial to this study. Memory limitations prevented some of the devices from being capable of logging more than 7 days of continuous driving data. Since our study sought behavioral information for representative weekdays and weekends, this limitation was unacceptable. Finally, several devices were eliminated from consideration because they required a cost-prohibitive service contract from the vendor for proprietary software that was not needed by the research team. The two devices identified with an asterisk in Table 1 were found to be the most suitable when each of these criteria was considered. The GeoLogger device was selected for this project, due to ease of downloading and cost.

For each device, the time between the vehicle start and the first recorded GPS data point depended on the time required to acquire a sufficient number of satellites for GPS positioning. This varies between 30 and 120 seconds even when sufficient satellites are present. Given this lack of information about the activity of the vehicle before satellite acquisition, realistic estimates of idling behavior when the vehicle was started would be impossible using only the GPS device. Therefore, the team decided to add an on-board diagnostic (OBD) device to provide engine-performance data that would be particularly useful during that initial start-up period. If the GPS device and the OBD device are synchronized by speed, then the engine-performance data from the OBD during the initial start-up could be substituted for the missing GPS data. Table 2 provides a list of the OBD devices evaluated for use on this project, with comments on their suitability.

Table 2 OBD Devices Evaluated

Device	Manufacturer	Comments
CarChipPro*	Davis Instruments	Missing data following the key-on. Unable to resolve with technical support personnel from Davis Instruments.
MiniDL*	EaseDiagnostics	Seemed to have the features needed.
DynoDashSPD	Auterra	More expensive than other options.

*Purchased and tested in vehicle.

Selection of an OBD device for use in this project was more straightforward than selection of the GPS device. Each of the devices evaluated was reportedly capable of providing the data needed. However, one was considerably more expensive than the others, and one of the devices tested seemed to have trouble recording data at start-up, resulting in omission of the precise data critical to this study. The MiniDL device by EaseDiagnostics was selected for this project.

2.2 Institutional Review Board Approval and Volunteer Recruitment

Measuring driving behavior of Vermonters required the recruitment of volunteer drivers and Institutional Review Board (IRB) approval at the University of Vermont. IRB approval was critical because human subjects were to be used in the investigation and those human subjects would not be fully informed about the purpose of the study. In order to avoid influencing the volunteers' normal idling behavior, the recruitment materials stated only that the study was intended to characterize driver behavior to improve transportation modeling. Obtaining IRB approval required that the project team develop a *Human Subjects Research Protocol*. The research protocol documentation included the following elements:

- Informed Consent Form
- Informed Consent Waiver (for a Deceptive Study)
- Recruiting Advertisement Language
- Volunteer Survey Questionnaire
- Data Storage and Security Plan
- Volunteer Reimbursement Plan

Each of the final elements of the protocol is included in Attachment A. Protocol approval was obtained from the University of Vermont on January 21, 2011.

Using this protocol, the team recruited drivers to represent a range of demographics and home locations in the state. Full demographic representation of Vermont drivers was not possible due to the limited sample size, but efforts were made to vary the age, gender, family status, and occupation of the participants selected for the study. To this end, the recruiting strategy consisted of gas-pump-top advertising billboards at three service stations in the following dispersed locations throughout the state:

1. Shell station at 75 S Winooski Ave in Burlington, Vermont
2. An independent station at 115 Main St in Orleans, Vermont
3. Lukoil station at 352 N Hartland Rd White River Junction, Vermont

Four (4) billboard faces were made available to drivers filling their gas tanks at each station. The billboard used is shown in Figure 2.

Help Improve Transportation for All Vermonters

VOLUNTEERS NEEDED

Free $25 Gas Card for Study Volunteers

The University of Vermont Transportation Research Center is looking for licensed drivers for a two-week-long study of driving behavior. A GPS recording device will be plugged into the OBD port of your vehicle and you will be asked to use your vehicle to travel as you normally would for a period of two weeks. During this time, the speed and location of your vehicle will be recorded and stored in the GPS device. All data collected will be anonymous and strictly confidential.

For additional information and to volunteer please see www.uvm.edu/~transctr

A $25 pre-paid gas card will be provided to all study participants.

Figure 2 Billboard Faces Used for Volunteer Driver Recruitment

The team used a incentive strategy ($25 pre-paid gas station gift cards) to increase the participation rate. As shown in Figure 2, potential volunteers were directed to the TRC website, where a link was set up to a recruitment survey. Preliminary demographic information was collected through the survey, and the participant's suitability for the study was assessed. Each of the questions included in the survey was consistent with questions used in person-section and the vehicle-section of the 2009 National Household Travel Survey (NHTS), which included 1,690 households in Vermont.

Completed surveys were received from a total of 40 people - another 13 potential respondents started, but did not complete, the survey. Eight of these respondents had vehicles that were unsuitable for the study – four of them drove hybrid vehicles, which do not idle, three drove vehicles manufactured before 1996, the year that OBD ports were first required in US automobiles, and one drove a motorcycle. Four other respondents withdrew during subsequent email communications, one volunteer had moved out of state, another would not be available for the Winter 2012 study, and two withdrew for undisclosed reasons.

Expecting that some of the drivers from the Summer 2011 study group might not be able to continue into the Winter 2012 study, the data collection was initiated with all 28 eligible drivers. At the start of the data collection, two vehicles were discovered to have faulty 12V power outlets and were dropped from the study, so 26 drivers completed the Summer 2011 data collection period.

Analysis of the summer data revealed a problem using data from vehicles where the 12V adapter did not shut off with the engine. Because of this problem, three volunteers from the Summer 2011 period were not asked to participate in the Winter 2012 period. In addition, one volunteer moved out of state, another did not respond to repeated scheduling requests, and a third could not participate due to a conflict with a car insurance study. The Winter 2012 data collection period therefore included only 20 returning volunteers.

3 Data Collection

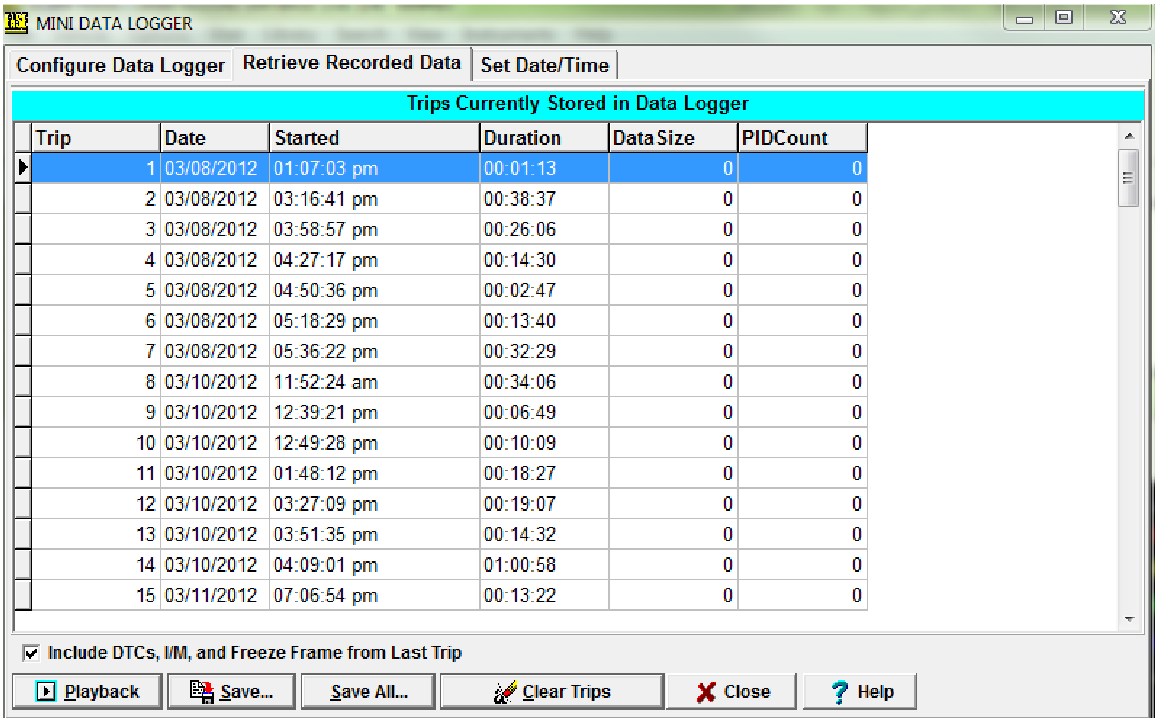
The data-collection period for each vehicle for this project was intended to be 14-days. Using a consecutive 14-day collection period ensures that weekday and weekend driving behaviors are represented in the data. Both devices were ascertained to have enough data logging storage for the average number of second-by-second data points that would be accumulated over a 14-day period. Seasonal representation was to be achieved by instrumenting each vehicle twice: once in warmer months of the summer and once in colder winter months.

UVM TRC staff coordinated with volunteer drivers to meet at their workplace so that the devices could be installed. At this initial meeting, drivers were provided a consent form to sign, the $25 gift card, and return packaging for the devices. UVM TRC staff developed the Participant Vehicle Set-Up Checklists (provided in Attachment B) to ensure that consistent, complete procedures were followed for all drivers during this initial meeting. Participants were contacted and reminded to return the data-collection devices once the 14-day period had elapsed.

3.1 Device Data Downloading and Pre-Processing

3.1.1 OBD Data

EaseDiagnostics, the manufacturer of the OBD data logger, provides a proprietary software package for accessing and exporting the recorded OBD data (see Figure 3). The OBD logger saves individual data files for each key-on to key-off vehicle operating-period as well as a single log file that contains summary metadata for each of these operating-periods. This metadata includes the date, start time and duration of each operating-period and is a prerequisite for synchronizing the OBD and GPS data. Unfortunately, the operations log is not downloadable and, therefore, accessing this data required obtaining a screen capture like the one in Figure 3 and use of character-recognition software to read the metadata off the screen capture. The individual operating-period data files contain the actual second-by-second engine performance data and can be exported as comma-separated-value files. To expedite the download process, all data files for a given day were saved in a single daily data file.



Trips Currently Stored in Data Logger

Trip	Date	Started	Duration	Data Size	PIDCount
1	03/08/2012	01:07:03 pm	00:01:13	0	0
2	03/08/2012	03:16:41 pm	00:38:37	0	0
3	03/08/2012	03:58:57 pm	00:26:06	0	0
4	03/08/2012	04:27:17 pm	00:14:30	0	0
5	03/08/2012	04:50:36 pm	00:02:47	0	0
6	03/08/2012	05:18:29 pm	00:13:40	0	0
7	03/08/2012	05:36:22 pm	00:32:29	0	0
8	03/10/2012	11:52:24 am	00:34:06	0	0
9	03/10/2012	12:39:21 pm	00:06:49	0	0
10	03/10/2012	12:49:28 pm	00:10:09	0	0
11	03/10/2012	01:48:12 pm	00:18:27	0	0
12	03/10/2012	03:27:09 pm	00:19:07	0	0
13	03/10/2012	03:51:35 pm	00:14:32	0	0
14	03/10/2012	04:09:01 pm	01:00:58	0	0
15	03/11/2012	07:06:54 pm	00:13:22	0	0

☑ Include DTCs, I/M, and Freeze Frame from Last Trip

Figure 3 Screen-Capture Needed to Obtain Metadata

The downloaded daily OBD data contains the following fields:

- Frame – the sequential record number of the downloaded data
- Time – the time elapsed from the start of recording (in seconds)
- TP – the absolute throttle position (% of full)
- VGFORCE – acceleration (G)
- RPM – the engine speed (rpm)
- VSS – the vehicle speed (mph)

Once the data had been downloaded from each device, several preprocessing steps were applied prior to the synchronization process described in Section 3.1.3. These steps included separating the daily data files back into individual vehicle operating-periods, identifying and indexing all of the ZSEs in the OBD vehicle speed data, and calculating several aggregate variables such as the total number of key-on events and total vehicle operating time across the entire study period.

Initial data assessment determined which derived variables were needed analysis. These new fields consisting of aggregated data that would be necessary to facilitate the analysis. Therefore, new fields were added in Matlab under three new data "structures" – a vehicle-based structure, a day-based structure, and an operating-period-based structure, from queries of the operating-period log and the daily data. The new fields created under these structures are described in Table 3.

Table 3 New Fields Created in the OBD Data Under New Data Structures

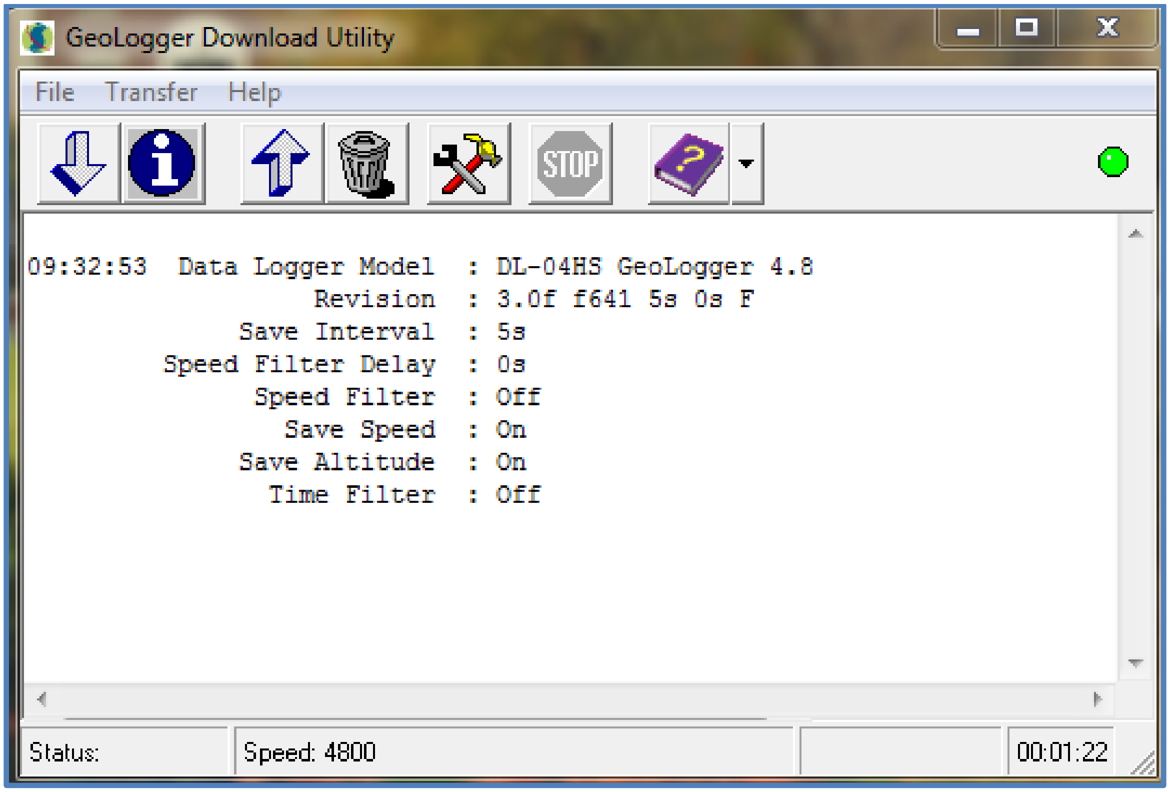
Variable Name	Description
Vehicle structure stores aggregate data from the vehicle over the study period.	
InstallDate	The date of the OBD installation
AnalysisDate	The first day the vehicle was driven after the InstallDate. Allows us to skip the install day in analysis.
ValidDate	The date of the first valid data file. Because the OBD records overwrite existing operating-periods when its memory is filled, this date is later than the StartDate for some vehicles.
FirstValidOperating-Period	The first operating-period with valid data.
AnalysisOperating-Period	Index to first operating-period to analyze. This is the first operating-period on the AnalysisDate if all operating-periods are valid, or the first valid operating-period if the ValidDate is later than the AnalysisDate.
TotalOperating-Periods	The total number of operating-periods in the operating-period log
ValidOperating-Periods	The total number of operating-periods with valid data
InstalledDays	Number of day the vehicle was instrumented
DriveDays	Number of days the vehicle was turned on while instrumented
ValidDriveDays	Number of days the vehicle was turned on and valid data recorded
ValidDayIndex	The day number of the first valid data file.
Day structure stores summary data for each day.	
Date	The date
ValidFlag	True if valid data is available for all operating-periods on this date
Operating-PeriodsPerDay	The totals number of operating-periods on this day
Operating-PeriodDuration	A vector with the duration of each operating-period on that day

Variable Name	Description
StartTimes	A vector with the start time (as fraction of 24-hours) for each operating-period
RawOBDData	May be faster than second-by-second
OBDData	Data in second-by-second format
Operating-period structure includes daily data for each individual operating-period (from a key-on to a key-off)	
Date	Date that the operating-period takes place
StartTime	Time of day that operating-period began
Operating-PeriodDuration	As recorded in the operating-period log
OBDData	Second-by-second daily data for this operating-period
OBDDuration	Duration of entire recording (seconds)
ZeroSpeedEvents	Duration of each zero speed event (seconds)
ZeroSpeedIndex	First and last rows in a zero speed event
ZeroSpeedOperating-PeriodEnds	Duration of ZSEs that occur at the start or the end of an operating-period (seconds)
PercentZero	Total zero-speed duration ÷ duration of entire recording

The OBDData variable saves the original daily data from the device. The critical new fields in the data set are ZeroSpeedEvents and ZeroSpeedOperating-PeriodEnds, which are used extensively in the subsequent analysis. Other new fields were needed for error checking and synchronization of OBD and GPS data. The complete code is included in Matlab functions under C0_CreateInputStructure and C1_OBDFunctions, provided in Attachment C.

3.1.2 GPS Data

Data logged by the GPS devices was available for download using the download utility provided by GeoStats (Figure 4).



```
09:32:53  Data Logger Model  : DL-04HS GeoLogger 4.8
                   Revision  : 3.0f f641 5s 0s F
              Save Interval  : 5s
         Speed Filter Delay  : 0s
               Speed Filter  : Off
                 Save Speed  : On
              Save Altitude  : On
                Time Filter  : Off
```

Status: Speed: 4800 00:01:22

Figure 4 GPS Data Download Utility

All data recorded to the GeoLogger is downloaded in a single file. The GPS data is recorded on a second-by-second basis and contains the following fields:

- Valid – flag identifying the first record after a satellite signal has been acquired
- Latitude – Latitude of the vehicle position
- Longitude – Longitude of the vehicle position
- Time – clock time (00:00:00)
- Date
- Speed – vehicle speed, in miles per hour
- Heading – direction of travel (0 to 360 degrees)
- Altitude – Altitude of the vehicle (feet above mean sea level)
- HDOP – horizontal dilution of precision (DOP) is an indication of the quality of the results that can be expected from a GPS point position
- Satellites – the number of satellite signals contributing to the GPS point position

Once the GPS data had been downloaded from each device, pre-processing of the GPS data began with the separation of GPS data by day and then into individual operating-period segments. A GPS operating-period segment is the set of continuous GPS records between instances of acquiring satellite lock, as indicated in the "Valid" field.

New variables were also derived from the GPS data stream that crucial to synchronizing with the OBD data and answering the specific research questions. These new fields consisted of aggregated data and were added in Matlab under the new data structures created previously for the OBD data. The new fields created under these structures are described in Table 4.

Table 4 New Fields Created in the GPS Data Under the New Data Structures

Variable Name	Description
Day structure stores summary data for each day.	
Date	The date
SegmentIndex	
SegmentsPerDay	
Elapsed	Elapsed time between records
DeltaHead	Heading change between two consecutive second-by-second records
DeltaDist	Distance change between two consecutive second-by-second records
OBDOperating-PeriodNumber	
OBDStartTimes	
StartTimes	
SegmentNumber	
Operating-period structure includes GPS data for each individual operating-period, from a key-on to a key-off.	
Date	Date that the operating-period takes place
StartTime	Time of day that operating-period began
Operating-PeriodDuration	As recorded in the operating-period log
OBDData	Second-by-second daily data for this operating-period

Variable Name	Description
OBDDuration	Number of seconds of records
Lat	Latitude of the vehicle position, directly from the downloaded data
Long	Longitude of the vehicle position, directly from the downloaded data
Speed	Speed recorded by the GPS device, directly from the downloaded data
ZeroSpeedEvents	Duration of each zero speed event
ZeroSpeedIndex	First and last rows in a zero speed event
ZeroSpeedOperating-PeriodEnds	Duration of ZSEs that occur at the start or the end of an operating-period
PercentZero	Total zero-speed duration / duration of entire recording

The critical new fields in this data set are Lat, Long, and DeltaHead, which are used extensively in the subsequent analysis to identify discretionary idling. Other new fields were needed for error checking and synchronization of OBD and GPS data. The complete code is included in the Matlab functions shown under C2_GPSFunctions, provided in Attachment D.

After the data had been separated into operating-period segments, several data quality checks were undertaken that revealed that the GPS data included many questionable records and many gaps in the second-by-second data. For any periods where the elapsed time ("Elapsed" in Table 4) between records was greater than one second, blank rows were inserted so that there is a record for each second in the GPS data stream. Questionable records, including those flagged in the "Valid" field, interrupted the speed and heading data with an abrupt change to 0 for one or more records, and then an abrupt change back to the previous values for these fields. These types of questionable GPS records have been noted in several prior studies by the team. The questionable records are often associated with low (less than 6) values in the Satellites field, but are not flagged in any way. Some of these instances can be identified by a deceleration or heading shift that is not physically possible, but others cannot be conclusively identified in any way. Questionable records were identified by calculating the distance between consecutive records and comparing it to the speed recorded by the GPS device.

DeltaDist calculates the distance traveled, d, from one GPS position, n, to the next, n+1:

$$d_n^{n+1} = R_{earth} * (2 * \sin^{-1}(\sqrt{((\sin((x_n - x_{n+1})/2))^2) + \cos x_n * \cos x_{n+1} * ((\sin((y_n - y_{n+1})/2))^2)}))$$

where R_{earth} is the radius of the Earth in feet (20,902,143.3) and x and y are the latitude and longitude of the coordinates, respectively, in radians

This distance was used to check for questionable speed data in the GPS records. Questionable records were flagged as such, for the heading and speed data, where this distance did not concur with the distance that should have been traveled if the speed between two consecutive points was accurate. Based on this assessment, and the fact that records between the key-on and the device's communication with satellites cannot be recorded in the GPS data, the team decided to rely on the OBD data for the base or reference vehicle speeds. The GPS data is of value for positional information: the latitude/longitude and the heading (although the heading data should be used with caution).

3.1.3 Synchronization of GPS and OBD Data

A synchronization process was implemented in Matlab to align each data stream based on the speed records. The synchronization process assigns GPS operating-period segments to corresponding OBD operating-periods based on the start times of the GPS operating-period segments and the OBD operating-periods. The process also concatenates GPS operating-period segments that are part of the same OBD operating-period into a single GPS operating-period. Because the GPS generally took longer to begin recording data than the OBD, the first record in the GPS data rarely corresponded with the first record in the OBD data. Instead, since both devices stop recording when the ignition is turned off, the process aligned the datasets backward from the final record in each dataset. To account for slight discrepancies in the sampling rate, the program automatically adjusted the alignment by a few seconds in either direction and selected the alignment that produced the highest correlation coefficient between the GPS and OBD speed records. The complete code for this process is included in the Matlab function provided in Attachment E.

In rare cases, the vehicle ignition was left in "accessory" mode after the engine was turned off resulting in a longer record in the GPS data than the OBD data. This caused a significant misalignment between the OBD and GPS speed, as shown in Figure 5. The Matlab code corrects this problem automatically by cutting the final string of zero-speed records in the GPS data to the same length as the OBD data. If there is missing GPS data in these records, however, this correction process is inadequate. In these instances, the correction had to be made manually.

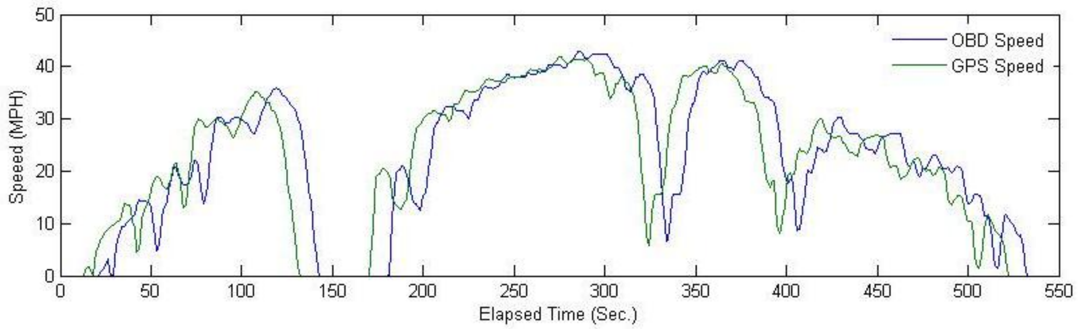


Figure 5 Misalignment of GPS and OBD Data Prior to Automated Correction Process

3.2 GIS Data Collection

In order to analyze the vehicle position data from the GPS, it was necessary to import the data into a GIS environment. For this analysis, a variety of GIS layers were gathered from the Vermont Center for Geographic Information (VCGI) to map the GPS points and determine if the vehicle was operating in the roadway at each point. The layers gathered include:

- Vermont Town Boundaries
- Vermont Town Parcel Boundaries

In addition, a layer of all roads and streets in Vermont, the rest of the New England states, New York, New Jersey, and Pennsylvania was used for the GPS analysis. This layer has exceptional coverage, even for minor roads, lanes, alleys, and some driveways, for the entire United States and its territories, based on 2007 Census Bureau files with additional enhancements by the Caliper Corporation.

4 Data Analysis and Results

Following pre-processing, the valid, usable OBD and GPS data for 17 volunteers in the summer group and 18 in the winter group was merged, yielding a total of 8,101 zero speed events (ZSEs) – 4,509 in the summer and 3,593 in the winter. The aggregate data set included data from 20 separate volunteers. Table 5 includes descriptive data regarding these 20 volunteers.

Table 5 Descriptive Data on Volunteer Drivers

Characteristic (continuous)	**Average**	**Maximum**	**Minimum**
Age (years)	37	54	22
No. of Vehicles	2	5	1
Persons in Household	3	5	1
Income Range[1]	$62,250	$100,000 or more	Less than $10,000
Self-reported Annual Miles	14,000	26,000	4,000
Vehicle Age	7 years	16 years	1 year
Characteristic (categorical)	**Most Common Answer**	**Second**	**Third**
Volunteer Gender	70% female	20% male	10% no answer
Home Ownership	60% own	40% rent	
Employment Status	85% full-time	5% part-time	10% no answer
Education[2]	40% bachelor's degree	40% graduate / professional	10% some college / associates degree
Type of Vehicle[2]	55% automobile / car / station wagon	15% SUV	5% van

Notes:
1. The average income range was found by using the mid-point of each income range.
2. The balance of the responses for these characteristics did not provide an answer.

All of the volunteers included in the study responded that they were the primary driver of their vehicle, and that no one else drove the vehicle regularly. The set of 20 volunteers reside in 14 different towns in Vermont and work in 12 different towns. Towns represented by volunteer's work and home locations are shown in Figure 6.

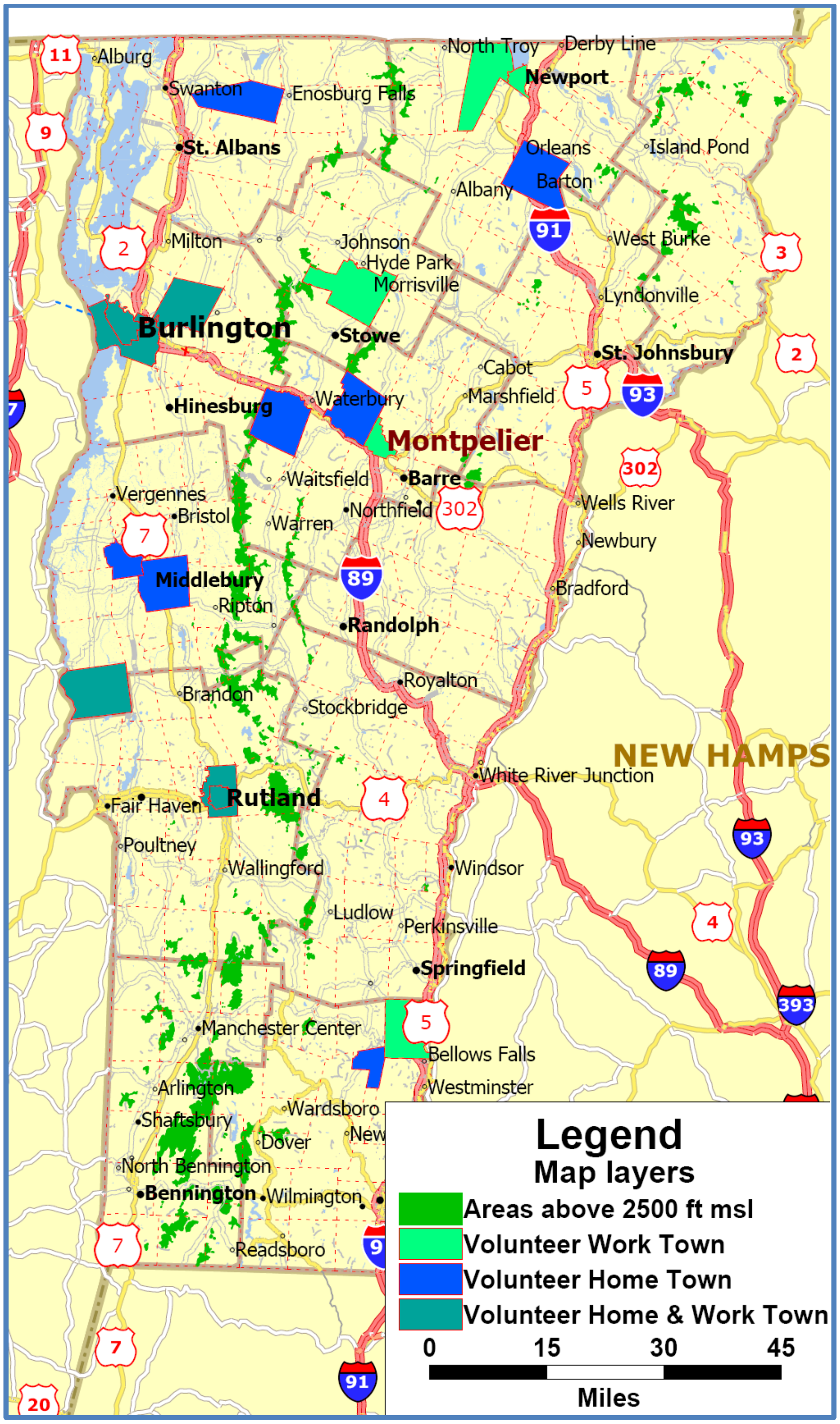


Figure 6 Towns Represented by Volunteer Drivers

The mean zero speed event (ZSE) duration was 17.4 seconds, with values ranging from 1 second to 1,244 seconds (21 minutes). The median value was 7 seconds and the mode was 1 second, indicating from the divergence of the mean and the median that the distribution was not likely to be normal. Indeed, the cumulative frequency distribution for the full set of ZSEs appears to be either lognormal or exponential (see Figure 7), with a majority of the durations under 30 seconds.

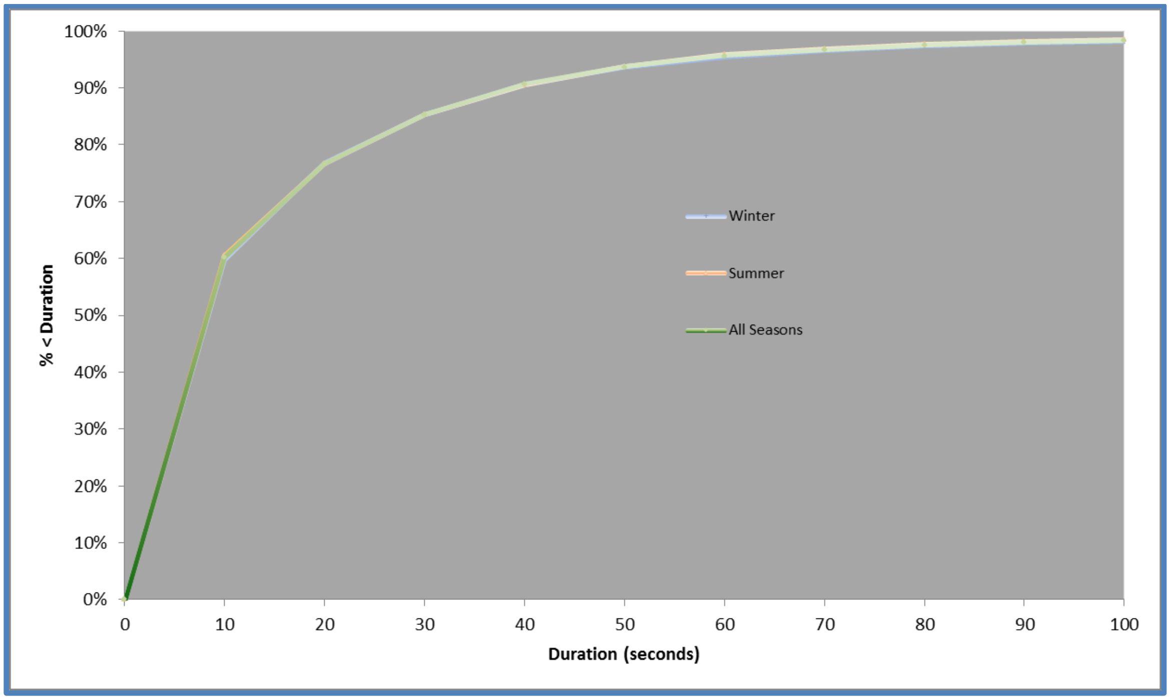


Figure 7 Cumulative Frequency Distributions of ZSEs

Statistical fit-testing was performed in Matlab, and the results indicate that the distribution is lognormal. The fit testing is illustrated in Figure 8.

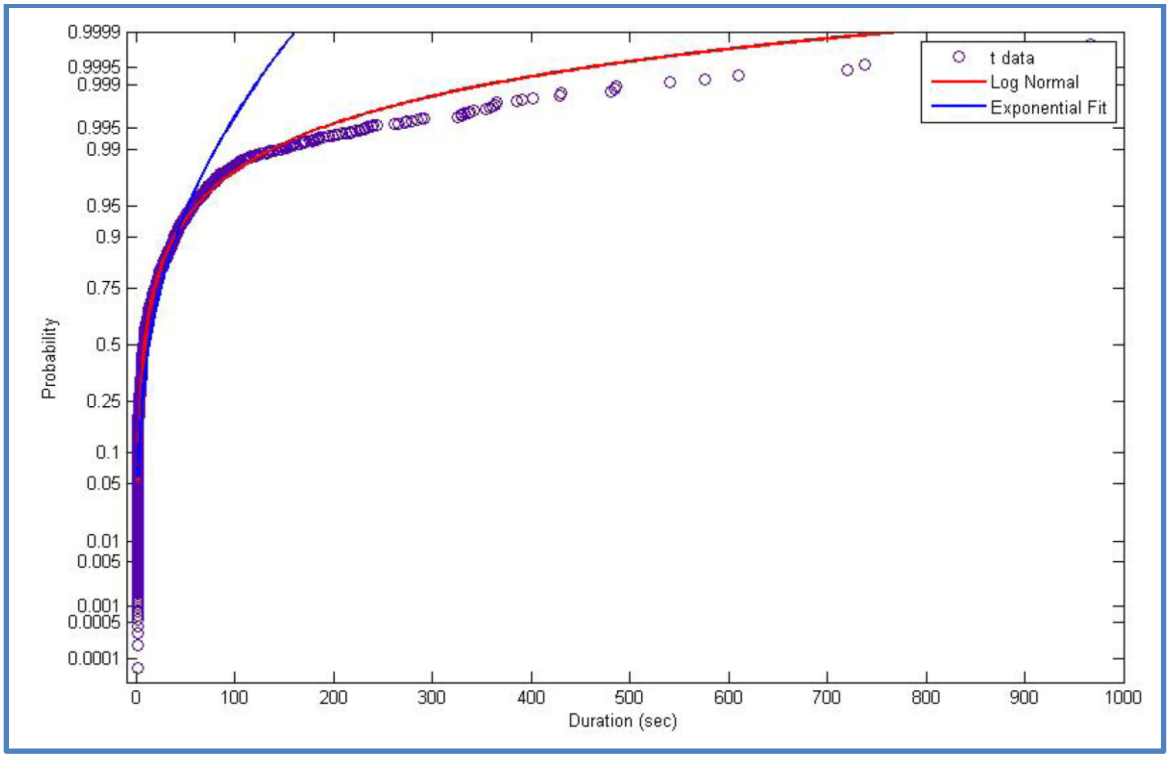


Figure 8 Fit-Testing of Cumulative Frequency Distributions of ZSEs

4.1 Data Processing Methods

For the entire data set, one spatial processing step and three non-spatial processing analyses were performed to yield ten (10) new fields of derived data.

4.1.1 Non-Spatial Processing Methods

The first step determined if the ZSEs in the merged data set occurred immediately following engine ignition (key-on) or immediately preceding turning the engine off (key-off), or if it occurs between the two (Intermediate trip-end). The complete code for this process is included in the Matlab function provided in Attachment F. Consequently, an additional field was created for all ZSEs with one of the following entries:

- Key-on
- Key-off
- Intermediate trip-end

This distinction is critical because ZSEs that occur immediately following or preceding an ignition-key turn are assumed to be under the control of the driver (discretionary).

The second process calculates the cumulative heading change 3-seconds, 5-seconds, 7-seconds, 10-seconds, 15-seconds, and 20-seconds before the start of the ZSE. The cumulative heading change, H, for each step back, n, was calculated as:

$H_n = \sum_{x=1}^{n} \Delta \hbar_{x-1}^{x}$ where h is the heading of each record x

The change in heading between any two consecutive records is calculated using a formula that handles the 360-degree orientation of the heading data:

$\Delta \hbar_{x-1}^{x} = \hbar_x + 360 - \hbar_{x-1}$ when $\hbar_x - \hbar_{x-1} \leq -180$

$\Delta \hbar_{x-1}^{x} = \hbar_x - 360 - \hbar_{x-1}$ when $\hbar_x - \hbar_{x-1} \geq 180$

$\Delta \hbar_{x-1}^{x} = \hbar_x - \hbar_{x-1}$ when $180 > \hbar_x - \hbar_{x-1} > -180$

Six additional fields of data were created by this process, each containing an integer heading change for the specified step back (3-seconds, 5-seconds, 7-seconds, 10-seconds, 15-seconds, and 20-seconds). Since the calculation is cumulative, each successive step back is greater than or equal to the previous one for each record. If questionable heading data were encountered as the process stepped back through the previous records, then the calculation yielded a null value, as did the successive values for that record. Therefore, as the process stepped further back from the state of the ZSE, it was more likely that questionable heading data would be encountered and null value returned for the cumulative heading change. The complete code for this process is included in the Matlab function provided in Attachment F.

Summary statistics for the heading change preceding each ZSEs are provided in Table 6.

Table 6 Heading-Change by Seconds Before ZSE

	Seconds Before ZSE					
	3-sec	**5-sec**	**7-sec**	**10-sec**	**15-sec**	**20-sec**
Minimum (degrees)	0	0	0	0	0	0
Maximum (degrees)	346	523	700	828	831	1,381
Count	7,405	7,298	7,210	7,090	6,893	6,719
Mean (degrees)	10.1	19.8	29.1	42.0	61.8	79.3
Standard Error (degrees)	0.3	0.5	0.6	0.8	1.1	1.3
Median (degrees)	1	4	6	11	20	31
Mode (degrees)	0	0	0	0	0	0
Standard Deviation	28.9	41.5	52.3	67.9	89.0	105.1

These values also suggest a distribution that is more exponential than normal, as shown in Figure 9, a histogram of the 10-second, 15-second, and 20-second lagged values.

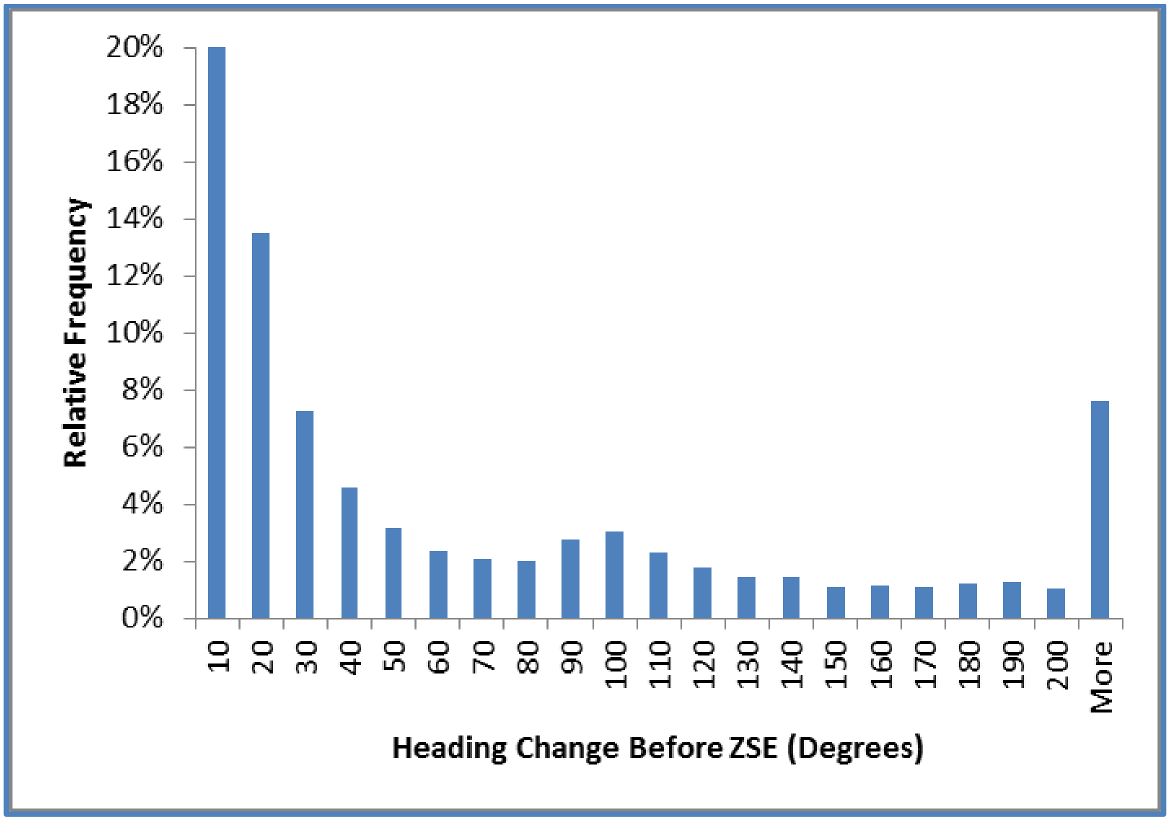


Figure 9 Histogram of Heading-Change for the 10-s, 15-s, and 20-s Lags

The histograms in Figure 9 also illustrate the tendency for the distribution to develop subtle peaks around 90 and 180 degrees.

The third process provides the best estimate of the vehicle's position for each ZSE and compares that to the known location of roadways from GIS. Since multiple GPS records are present for each ZSE, this process used all of the individual second-by-second records for the ZSE to get the best estimate of position. However, the pre-processing of the GPS data filled in records where data was missing, so null values are present in the latitude and longitude fields of some GPS records. Therefore, taking the average of all the ZSE position records would not be accurate. Instead, the team decided to use the mode of the valid position records as the final position of the ZSE. For those ZSEs without any valid position records, the valid moving position that is closest in time to the ZSE was used as the final position. In this way, a final latitude and longitude for each ZSE was determined, creating two additional new fields in the ZSE data. The complete code for this process is included in the Matlab function provided in Attachment F.

4.1.2 Spatial Processing Method

The spatial method of distinguishing the intermediate trip-end ZSEs (discretionary idling) from the traffic related ZSEs consisted of a tiered selection which took advantage of the Vermont Town Boundaries layer, the 170 Vermont Town-Based Parcel Boundaries (of the 254 towns in Vermont) layer, a nationwide layer of roads and streets in the United States and Canada from the Caliper Corporation, and the locations where ZSEs occurred.

For the ZSEs that occurred in a Vermont town with a parcel layer (87%), the parcels representing the roadways were selected from each town's parcel layer, and an initial selection of the ZSEs that are within the roadway was performed. For the ZSEs that occurred outside of Vermont or in a Vermont town where no parcel layer was available (13%), the distance to the nearest road or street was determined using the "Tag" function in TransCAD. Tagging consists of filling in a new field in a layer's data table with the distance to the nearest feature in another layer (in this case roads). This procedure was repeated for the ZSEs that had already been selected. The vast majority of the points already in the selection set (90%) were found to be within 25 feet of the centerline of the nearest road or street. This distance fits the expectation for the maximum distance a vehicle would be from the centerline of a road to still be traveling on that road, since typical roadway lanes vary from 9 to 12 feet. So even on a roadway with three lanes in either direction, the vehicle is likely to be less than 25 feet from the centerline. Based on this observation, all points that were within 25 feet of the centerline of a road or street were added to the selection set of en-route or traffic related ZSEs. This estimation is likely to incur considerably greater error than the identification of ZSEs within the roadway parcel used for the first set. However, the relatively low number of points for which this step was necessary (13%) encourages the team to assume that the overall effect on the results is minor. The final selection set was identified as the set of ZSEs that occurred "in traveled way". Selected statistics related to this selection set are shown in Table 7.

Table 7 Descriptive Statistics of the Final Spatial Selection Set

	Summer		Winter	
	Not In Traveled Way	In Traveled Way	Not In Traveled Way	In Traveled Way
Count	1,939	2,569	1,368	2,225
Average ZSE Duration (seconds)	17	16	22	16
Average 3-Second Lag (degrees)	18	6	16	5
Average 5-Second Lag (degrees)	37	10	33	11
Average 7-Second Lag (degrees)	54	15	49	16
Average 10-Second Lag (degrees)	77	23	71	23
Average 15-Second Lag (degrees)	112	34	104	35
Average 20-Second Lag (degrees)	142	46	131	47
Avg Dist. to Nearest Street (feet)	99	13	97	12

These results demonstrate the apparent relationship between ZSEs that occur in the traveled way and the heading change that occurs before the start of the ZSE. As expected, greater preceding heading changes are associated with ZSEs outside of the traveled way at trip ends, where parking maneuvers and turns are more common.

Both spatial selection methods are also vulnerable to the error in the accuracy of the GPS device itself. When weaker satellite coverage is available for the device to calculate its position, the resulting coordinates may create error that affects our tabulation. To combat this effect, as explained previously, the research team used the mode from the set of second-by-second points representing the vehicle's position at the ZSE. Therefore, the impact of the accuracy of the GPS device is minimized.

4.2 Data Analysis

4.2.1 Separation of Discretionary and Non-Discretionary Idling

The primary goal of this project is to provide an improved understanding of PV idling behavior. Providing this understanding requires distinguishing between idling behavior that can be prevented by the driver (discretionary) and the time a vehicle is idling simply because the traffic stream is motionless (non-discretionary). In the Data Processing steps, ZSEs were identified as in or out of the travelled way and at turns of the ignition-key, and heading changes preceding each ZSE were calculated at intervals between 3 seconds and 20 seconds.

In order to distinguish discretionary idling, the team explored two separate methods – one based on the spatial processing steps and one based on the non-spatial processing steps. For the spatial-based method, the team simply added the ZSEs that were not in the traveled way to those that were in the traveled way but occurred following or preceding a turn of the ignition-key (key-on and key-off). This set of ZSEs is assumed to be discretionary – that is, the duration of the ZSE is under the control of the driver.

For the non-spatial method, the ZSEs identified as preceding the turn of the ignition-key (key-off events) were extracted as a representative sample of known discretionary ZSEs. The team expected, based on the spatial processing results (Table 7) that discretionary ZSEs are commonly preceded by a significant heading change, whereas non-discretionary ZSEs are not. Using this assumption, the 20-second heading-change for this set of ZSEs was analyzed to identify a minimum that could be used to distinguish "significant" heading changes. As shown in Figure 10, there is an inflection point in this distribution of heading changes at 88 degrees.

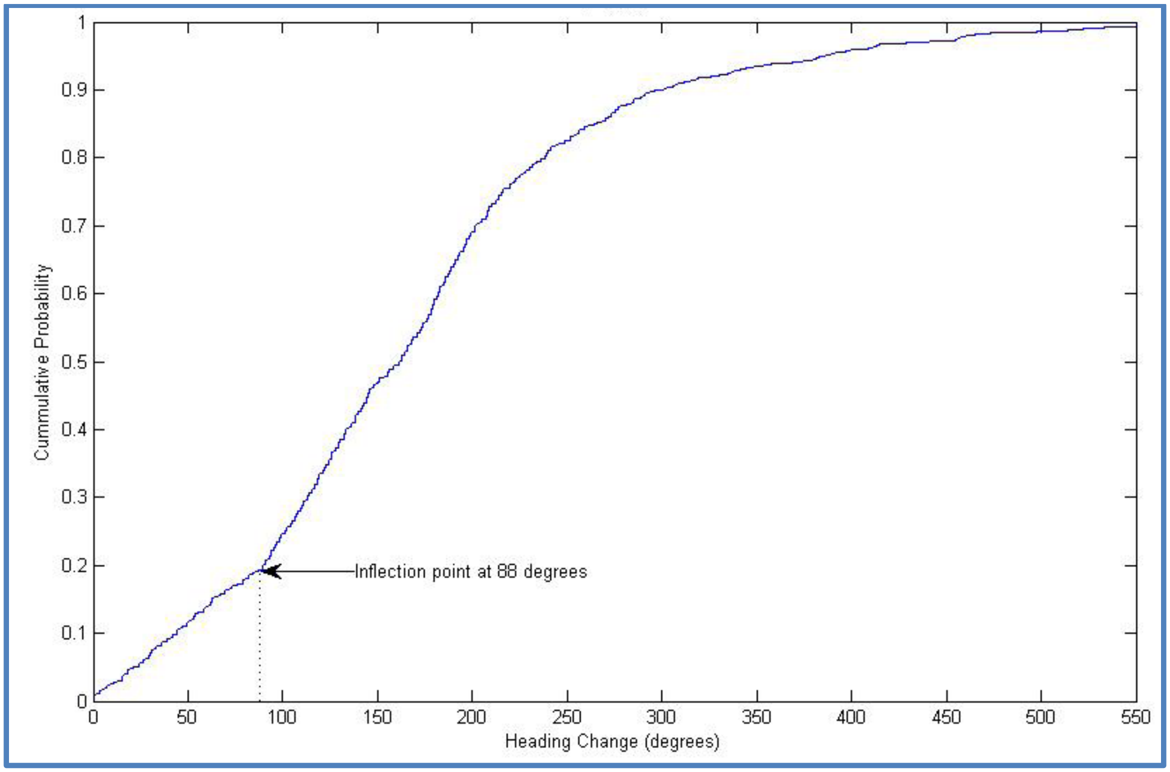


Figure 10 Cumulative Frequency Distribution of Heading-Changes Preceding Key-off ZSEs

Therefore for this pilot study, the non-spatial method of distinguishing discretionary idling from non-discretionary idling will use the total 20-second heading change of 88 degrees. The next phase of this project will require this threshold to be more accurately determined. ZSEs with more than 88 degrees of heading change in the 20 seconds preceding the ZSE were considered discretionary, while those with less than 88 degrees of heading change were considered non-discretionary.

The non-spatial method of distinguishing discretionary ZSEs yields a smaller number of events (2,893) than the spatial method (3,627), with 2,316 events in common. The means of the two sets of ZSEs, however, very similar – 19.5 seconds for the spatial method and 19.3 seconds for the non-spatial method. In addition, the distributions are relatively similar (Figure 11).

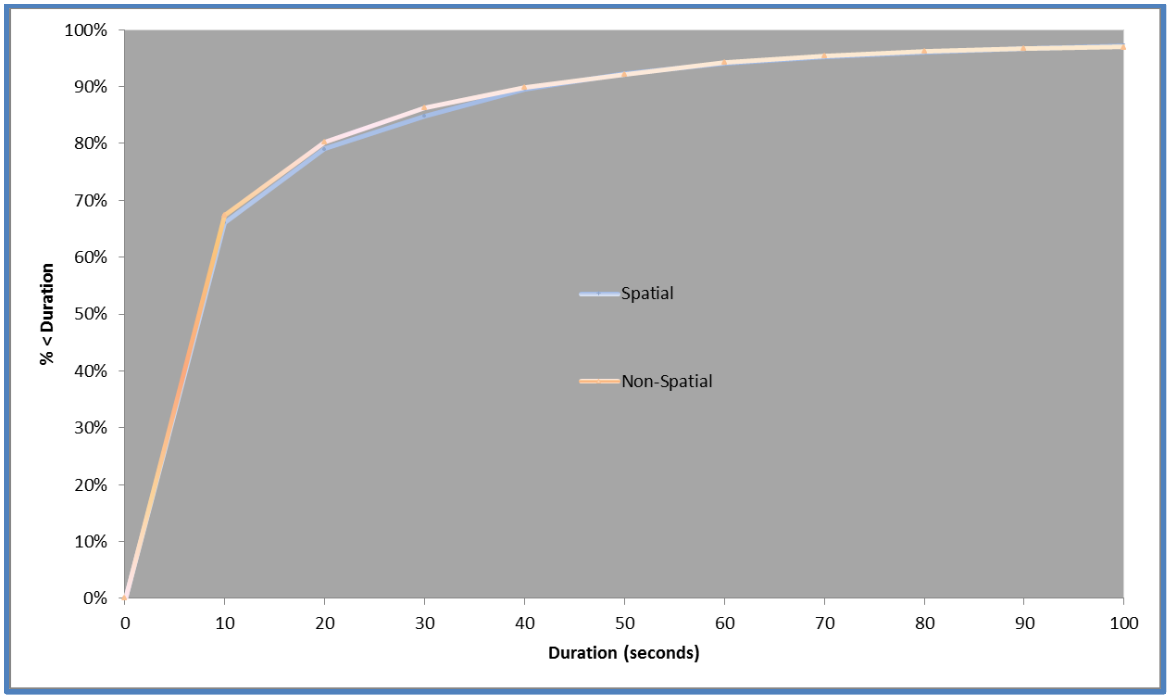


Figure 11 Cumulative Frequency Distributions of the Spatial and Non-Spatial Sets of Discretionary ZSEs

Based on these findings, the intersection of the two sets of ZSEs is the most conservative and therefore reliable representation of discretionary ZSEs. Therefore, this set of events identified by both the spatial and non-spatial method are used for analysis of discretionary idling in the next subsection.

4.2.2 Comparison of Winter and Summer Discretionary Idling

Once discretionary and non-discretionary ZSEs had been separated, detailed statistical analyses of the durations of these sets were undertaken. For discretionary ZSEs, winter and summer, the arithmetic means were calculated, as shown in Table 8. As noted previously, though, these distributions fit a lognormal form better than a normal form. Therefore, for each set, the lognormal parameters μ and σ were estimated to fit the exponential probability density function:

$$y = \frac{1}{x\sqrt{2\pi\sigma^2}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$$

The results of the lognormal parameter estimations and the resulting lognormal distribution descriptive statistics are shown in Table 8. The same summary statistics are also provided for the entire data set, including all 8,101 Winter and Summer ZSEs, for comparison purposes only, the winter and summer periods do not include the exact same set of drivers.

Table 8 Selected Statistics for the Final Set of Discretionary ZSEs

	Discretionary Idling			All Zero-Speed Events		
Parameter or Statistic	Both Seasons	Winter	Summer	Both Seasons	Winter	Summer
General Characteristics of Durations of ZSEs (seconds)						
Maximum Value (s)	1,244	1,244	720	1,244	1,244	720
Sum	47,435	24,815	22,620	140,833	65,171	75,662
Count	2,316	1,004	1,312	8,101	3,593	4,508
Arithmetic Mean (s)	20.5	24.7	17.2	17.4	18.1	16.8
Assuming a LogNormal Distribution of Durations of ZSEs						
μ	1.98	2.05	1.93	2.04	2.05	2.04
σ	1.25	1.33	1.18	1.24	1.25	1.23
Expected Value (s)	15.9	18.8	13.9	16.6	16.9	16.3
Median (seconds)	7.3	7.8	6.9	7.7	7.8	7.7
Mode (seconds)	1.5	1.3	1.7	1.7	1.6	1.7

A review of the arithmetic means and the expected values of these distributions (highlighted in Table 8) clarifies the importance of the distributional assumption of log-normality. Although the differences between the winter and summer become more pronounced when discretionary events are separated, these differences are muted when the expected values f the lognormal distribution are considered. The expected values of the lognormal distribution reflect the true nature of the distribution. That is, the clustering of values near the mode, which bring the expected value down closer to the mode. Therefore, consideration of the arithmetic means only could lead to the erroneous conclusion that ZSEs are different for winter and summer in the entire data set, as well as in the discretionary data set. In fact, statistical testing indicates that the winter and summer distributions of all ZSEs are not significantly different (F-test indicates a 30% chance that the two samples come from the same population; two-sample Kolmogorov-Smirnov test indicates a 63% significance level for the hypothesis that the distributions are the same), but the winter and summer distributions of discretionary ZSEs are significantly different (F-test indicates a 0.01% chance that the samples come from the same population; two-sample Kolmogorov-Smirnov test indicates a 2% significance level for the hypothesis that the distributions are the same).

The cumulative frequency distributions of the set of discretionary ZSEs are shown in Figure 12, along with the arithmetic means and the expected values (E).

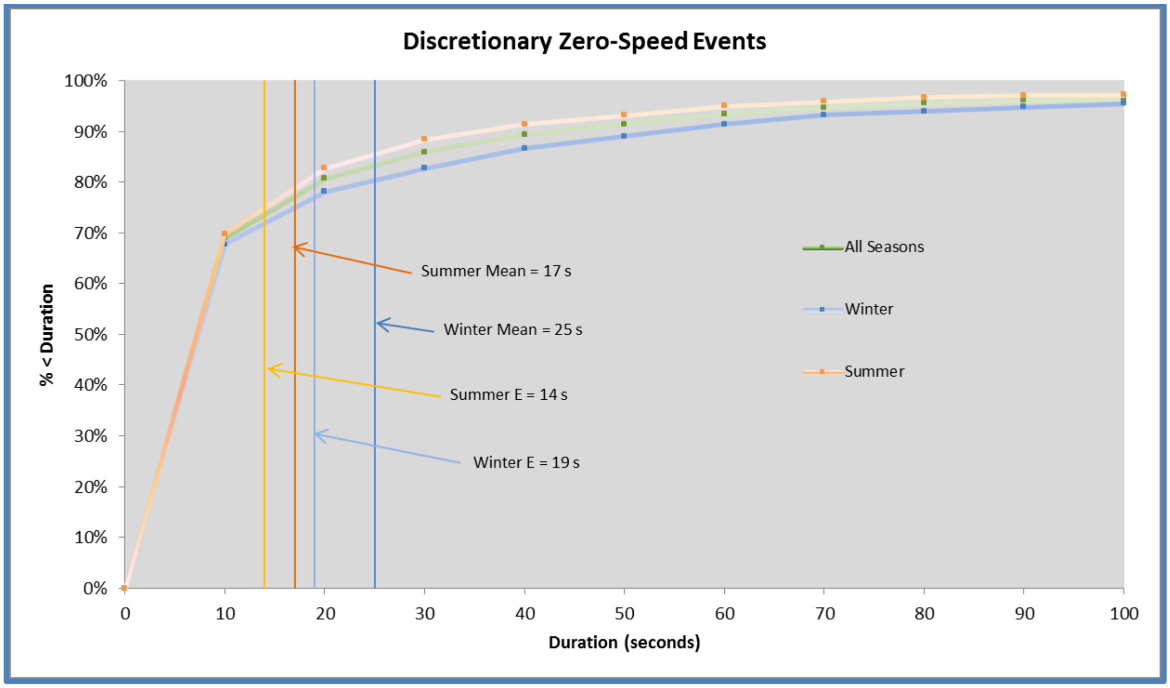


Figure 12 Cumulative Frequency Distributions of Discretionary ZSEs

In contrast to Figure 7, the cumulative frequency distributions shown in this figure diverge significantly above 10 seconds in duration, and particularly between 10 seconds and 100 seconds. This divergence is reflected in the winter E, which exceeds the summer E with statistical significance, and in the estimated 85th percentiles of each distribution, which are 36 seconds and 23 seconds for winter and summer, respectively.

4.2.3 Daily Discretionary Idling in Vermont

Another way of assessing patterns of vehicle idling seasonally is to examine the daily discretionary idling behavior of Vermont drivers. This determination allows us to examine the potential effects of reducing or eliminating discretionary idling on annual greenhouse gas (GHG) emissions from PV idling. Table 9 summarizes the number of days of usable data yielded by each volunteer, and idling seconds per day by each volunteer, separately for summer and winter.

Table 9 Daily Discretionary Idling By Volunteer

	No. of Days of Data		Daily Discretionary Idling (seconds per person-day)	
Volunteer No.	Summer	Winter	Summer	Winter
1	0	13		5
2	14	5	15	22

3	0	7		17
4	8	13	6	32
7	15	15	11	80
11	7	10	5	4
12	12	1	30	0
13	15	14	39	15
14	15	7	20	95
15	12	13	7	43
16	9	15		86
17	7	4	85	15
19	8	0	54	
20	0	13		229
21	16	5	21	23
22	15	0	34	
23	3	4	14	5
24	16	11	6	53
25	13	13	18	33
26	11	9	9	103
Average Discretionary Idling (seconds per person-day)			**23**	**48**

The differences between winter and summer are quite significant when daily discretionary idling is considered. As evidenced by the average idling figure highlighted at the bottom of the table, daily winter discretionary idling exceeds summer idling by over 100%. If this aggregate estimate is factored up to all of Vermont's 518,460 drivers (VTrans, 2012), total daily discretionary winter idling could be in the neighborhood of 6,912 hours. Using the EPA estimated emission of an idling vehicle of 19.4 lbs/hour (USEPA, 2005), a crude estimate of 67 tons of CO_2 is released per day by discretionary idling in the winter in Vermont.

4.2.4 Differences in Trip Start and Intermediate Trip End Idling

There were three types of discretionary idling identified in this study: trip start at key-on, trip end at key-off and intermediate destinations.

Of the 8,101 idling events in the dataset, 233 events were longer than 60 seconds. The sample mean, number of events, and lognormal parameters for the events for each trip stage are shown in Table 10. The two-sample KS test showed a significant difference in the distributions of trip-starts and intermediate trip-ends at the 0.05 significance level and between trip-starts and final trip-ends at the 0.1 significance level. The test showed no statistically significant differences between the distribution of intermediate and final trip-ends.

TABLE 10 Average Durations of Idling Events over 60 seconds by Trip Stage

	Type of Discretionary Idling Event		
Parameter or Statistic	Trip-Start Idling	Intermediate Trip-End Idling	Final Trip-End Idling
Sample Mean (seconds)	219	129	125
Count	71	125	37
Μ	5.1	4.7	4.7
Σ	0.8	0.5	0.5

The longest discretionary idling events follow key-on in the winter, likely reflecting some combination of the driver's desire to warm the interior of the vehicle and the belief that the vehicle's engine needs to be "warmed up" before it will perform well. Isolating a sub-grouping of the events following the key-on to include only the first events of the day for a given volunteer causes the average duration to grow to 127 seconds, further supporting this hypothesis. Unfortunately, the sample size of idling events at this point is low, so this finding should be considered preliminary

5 Discussion of Enforcement Implications from Data

The results described in the previous section attest to the potential for reductions in GHG emissions from transportation that are possible with reduction or elimination of discretionary idling in Vermont. This project also begins to identify guidance as to best targets for programs or policies that will motivate that reduction. The vast majority of the discretionary idling events identified in this study fall below the minimum levels of between 30 and 60 seconds targeted by most reduction efforts. Therefore, enforcement of any type of anti-idling legislation will be difficult and education programs may have more effective potential.

This study helps identify the temporal trends in discretionary idling as well as the presence of high idling outliers that might make this enforcement more feasible. The difference between summer and winter idling grows as the shorter, unenforceable events are removed from the data set. We recommend a future focus for research on the temporal and spatial patterns of the most serious and longer instances of discretionary idling.

6 Conclusions and Future Work

The primary goal of this overall project is to improve our understanding of discretionary idling behavior by Vermonters, including the variations in PV idling behavior in urban and rural towns, between demographic groups, and by season. This report documents the first year of the project, which set out to pilot-test the implementation of a comprehensive data collection method and spatial analysis techniques for the study of idling behavior of Vermont drivers. The results of the Year 1 pilot implementation developed solid protocols for driver recruitment, data management, and data analysis. The successful aspects of the research protocols included:

- Driver recruitment through gas-pump-top billboard advertising
- Vehicle selection for instrumentation
- OBD and GPS equipment selection and utilization
- OBD and GPS data downloading, management, quality analysis, and synchronization
- Second-by-second driver-behavior data analysis, including separation of discretionary and non-discretionary ZSEs
- Statistical and spatial analysis of discretionary idling data

These solid protocols can be applied with greater efficiency in the implementation of a full-scale study in the next years of the project. This efficiency is particular important as larger sample sizes are needed to better estimate total carbon emissions associated with discretionary idling as well as the patterns of idling that will inform programs and enforcement efforts.

This preliminary data did allow for the development of an initial understanding of the seasonal differences in idling behavior. The pilot-scale results indicate that significant difference in discretionary idling behavior exist in Vermont between seasons. Vermonters tend to idle longer, as measured by individual ZSEs and total daily idling, in winter than in summer. Additionally, these results showed that the additional winter idling can be attributed primarily to the initial car “warming” event when the key is turned on for the first time each day. These findings suggest that policy actions, efforts to influence behavior, or enforcement actions may need to focus on initial engine-start ZSE in winter in Vermont.

A more in-depth understanding of the spatial and demographic differences in PV idling behavior requires a larger sample size. In the second year of the project, the goals will be to recruit 100 or more volunteer drivers for a similar analysis. This time, additional efforts will be made to ensure good demographic and spatial representation of the volunteers, so that the most likely locations and the most likely perpetrators of long discretionary-idling events can be identified. With more volunteer drivers, we will also be more confident in our state-wide estimates of GHG emissions and fuel-use resulting from discretionary idling. This understanding will help policymakers understand the urgency of the problem as well as the GHG benefits that will accrue to program success. The understanding of the spatial and temporal patterns of discretionary idling will help develop targeted strategies to reduce or eliminate this behavior, and assist the enforcement of existing discretionary-idling limits in places like Burlington.

Year 2 of this project builds upon the first year of the project by expanding the study to a more robust sample size. In addition to difference by month we recommend recording actual temperature data on the days of data collection. Models of discretionary idling event duration are recommended that will utilize location type, household and vehicle characteristics to better inform future legislative restrictions on passenger vehicle idling as well as the associated education and enforcement.

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