Evaluation of ODOT Roadway/Weather Sensor Systems for Snow & Ice Removal Operations - Part V: Vehicular Speed Associated with Winter Pavement Conditions

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Prepared in cooperation with the Ohio Department
of Transportation and the U.S.
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16. Abstract

The major objective of the study was to develop a procedure to determine the level of service using the RWIS speed measurements. The procedure developed can be used by ODOT to evaluate winter maintenance activities and for winter maintenance decision making. Average traffic speeds for five minute intervals were measured using NuMetrics road sensors and they were related to the pavement and driving conditions. In addition speed data from two other studies was used. The pavement conditions were determined by conducting surveys at rest area buildings using a questionnaire form. It was found that the average traffic speeds were significantly lower during a major snow event even when periodic plowing and salting was done. The average speeds decreased almost linearly for the period of the snow storm reached the minimum and then climbed back slowly towards higher speeds. The speeds appear to be a fairly sensitive measure to judge the condition of the pavement. The motorist judgments about the pavement condition and their perception of the safety of driving decreases during a rather severe winter storm which is mirrored in the speed decrease. It appears from the survey that about two thirds of the motorists judge the detoriation of the road conditions and the inadequate level of road maintenance during a winter storm as bad or moderately bad. The responses obtained for the car and the truck drivers are fairly close to each other indicating that both groups can judge bad road condition equally well. The observed road conditions appear to influence the drivers in terms of how they subjectively feel about the level of safety and stress experienced during driving in the winter storm. A simple procedure was developed for winter maintenance management to determine the condition of the road (freeways) based on the average speeds observed by the RWIS sensors. If the average winter speed of the traffic is equal or greater than the historical established wet/salted pavement speed, the level of service is considered adequate. According to the Swiss study, the wet/salted surface winter speeds are about 85% of the dry surface speeds for freeways and 96 % for city streets. If the average winter speed is below the wet/salted surface speed, the level of service is considered inadequate. Any speed less than 50% of the wet/salted surface speed indicates fairly bad road conditions and an extremely inadequate level of service. It should be noted that the winter pavement conditions can be highly dynamic. Depending on the rate of accumulation of snow, frequency of the snow plowing, length of the snow plow route, the pavement condition can improve and detoriate a number of times during a winter storm. The level of service can get worse even with maximum snow plowing and salting effort in a situation with a high rate of snow accumulation. The winter speeds observed as a percentage of the average dry surface speed can be correlated with the level of service. A relatively more fine graduation of the level of service as a function of the percentage of the average dry surface speed is proposed in the recommendations of the report.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

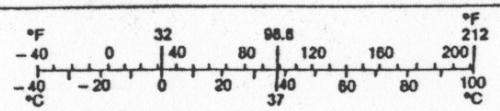
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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Ohio Department of Transportation
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1. INTRODUCTION

The level of service during a winter storm event measures the efficiency and effectiveness of anti-icing measures taken to counter it. According to [5], Level of service is a qualitative measure describing operational conditions within a traffic stream. Level of service assesses conditions in terms of speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety. Six levels of service are defined by letter designations from A to F, with Level of service A representing the best operating conditions, and Level of service F the worst. Level of service is also closely related to road surface conditions, which in turn are an estimate of the amount of friction the road surface can provide for automobiles. Currently the road slipperiness and surface conditions are estimated subjectively by field personnel based on visual inspections and input from the local driver. Objective surface condition criteria would help enormously to create and maintain uniform pavement surface condition standards across multiple jurisdictions. Two such measures are road friction as measured using a mobile friction tester [3] or a stationary remote surface state sensing instrument- Cyclo &Spectra [7] by Vaisala and traffic speed as measured by Ohio's expanded RWIS network pavement sensors and existing induction loops. The friction tester gives an objective measure of road friction, however there are a limited number of these available and they cannot be deployed in large enough numbers statewide. The RWIS network is statewide, however, and it will provide speed data as well as weather and pavement surface status information. The average speed data will be used to develop a procedure to determine the level of service in terms of the RWIS station speed measurements.

With the average winter traffic speeds available from RWIS sensors embedded in the road, a new procedure is developed to determine the condition of the roadway in a more objective way and in near real time. Ohio's RWIS (Road Weather Information System) is a network of weather stations each containing a number of different sensors that gather weather and pavement data and then report the data via electronic communication links to a central location where authorized personnel can view and use the information in their winter maintenance decision making process. There are a total of about 170 RWIS stations in the state of Ohio out of which about 80 RWIS stations have 330 NuMetrics sensors installed in the pavement to report the average traffic speed and the traffic volume data in addition to the standard pavement parameters like surface temperature, surface status, etc. ODOT's RWIS system records data every five minutes at minutes ending in one and six after the hour.

One of the underlying objectives of this research is to develop a procedure to determine the level of roadway snow and ice control operations in terms of the average speed measurements reported by the Nu Metrics sensors which relates to the level of service. Since most drivers reduce their speed upon perceiving potentially hazardous road conditions caused by snow and ice, the average speed data obtained from the RWIS sensors can be correlated to the level of service. In winter roadway conditions, friction plays a very important role in the safety of the traffic. The determination of the stopping distances serves as an indicator of relative security [2].The stopping distance is a function of reaction time and braking distance. The condition of the roadway determines the braking distance. The coefficient of friction on a dry roadway is usually much greater than it is on a wet/salted roadway. Therefore it takes more braking distance for the driver to stop on a wet/salted roadway at greater speeds than on a dry roadway. So a relationship between braking distances with different roadway conditions needs to be established quantitatively to ensure a good level of service.

2. OBJECTIVES OF THE STUDY:

The objective of this study is to develop a procedure to determine the level of service in terms of the RWIS station speed measurements. This procedure may also be validated by ODOT road friction measurements with friction data. The aim is then for ODOT to objectively measure average vehicle speed and weather information on the RWIS network, thereby deriving the level of service for winter maintenance operations in that area. Based on the literature review and the driver surveys the research includes:

- Discovery of existing research on travel speed, variables involved in a winter weather event, and human factors as related to winter weather.
- Evaluation of variables affecting travel speed
- Evaluation of travel speed and possibly volume as indicators of road conditions during a winter weather event.
- Collection and analysis of supporting data associated with winter events through various measurements and visual documentation.
- Establish historical average travel speeds and/or volumes for selected highway locations in Ohio under clear and dry conditions for day and night. The travel speeds were established for driver surveys at rest area 04-440 on IR- 271 southbound and rest area 04-36 on I-76 westbound I-76 before, during and after a winter storm event.
- Establish the relationship between travel speed and RWIS weather data to driver's comfort level and perceived level of service.
- Classification of criteria affecting levels of service for winter weather events on selected highway sections in Ohio.
- Development of criteria for identifying the level of service.

3. RESEARCH APPROACH AND METHODOLOGY

There were two main thrusts to the research effort:
1. The determination of factors that affect speed and use of historical speed data correlated to level of service and 2. Determination of level of service or presence of hazardous road conditions as perceived by Ohio's drivers. These aims were pursued in parallel.

The first aim was pursued with a literature search and brief survey of state DOT's to see what has already been done to traffic speed to level of service. The search identified other factors that can affect travel speed and ways to distinguish them from winter storm effects. Human factors and other variables in a winter weather event were also considered. The survey was primarily focused on driving speeds in winter. The results of this search were used to identify what variables affect travel speed in winter.

Initially it was planned that four sites in the northern Ohio Snow Belt be selected for collection of speed data. These will be Nu Metrics installations or perhaps inductive loop installations if they provide the sufficiently fine (15 minutes or less) near-real-time resolution. Likely sites include the three Nu Metrics installations on I-90 in Ashtabula County, with the Conneaut site looking the most promising, and the Nu Metrics sites in Medina County, the border of Summit and Medina Counties, and the border of Summit and Portage Counties. Level of service information will be collected for these sites during storm events and related

to speed and volume data measured at the same time. The results will be analyzed to find a relationship between weather condition, level of service, and speed. Statewide historical average travel speeds and volumes for selected Ohio highway sections under clear and dry conditions during day and night will be obtained using ODOT's databanks and input. These data may be validated against friction data collected by ODOT for this project. The analysis was done for two sites only instead of four sites because there were no big snow storm events in the project duration period and the report documents the results obtained from these two field surveys. The data from [2] was used as a replacement to develop a procedure to determine the level of service. The friction data was not used for validation due to lack of data.

For the second track, a survey of Ohio motorists was conducted to assess their perceptions of comfort level and level of service. It will be administered for the period of the snow storm at modern rest areas buildings along interstates in northern Ohio during winter weather events. The likely locations for this effort were considered to be the rest area on I-90 at Conneaut and the rest area on I-271 at the border of Summit and Medina Counties. The goal was to get input from at least 100 motorists per day responding to the survey. Eventually the driver surveys were conducted at rest area 04-440 on I-271 southbound and rest area 04-36 on I-76 westbound.

All these data were used to create a classification of criteria affecting levels of service for snow and ice conditions. This includes a correlation of average speed to level of service during winter weather events. Using the results, it will be possible to take speed, plus other objective data such as weather information, and identify the level of winter service. These criteria can also be used to assist in winter maintenance decision making, helping to ensure consistency throughout the state.

4. BACKGROUND AND SIGNIFICANCE OF WORK:

Presently ODOT determines the winter maintenance level of service qualitatively through visual inspections and driver feedback. While customer satisfaction is always the ultimate determinant of the quality of service, it is not always uniform, consistent, or objective. A more objective measure of winter service is the friction level of the road. To this end, ODOT has purchased a number of road friction testers developed by Halliday Technologies Inc [3]. These will be mounted on snowplow trucks and deployed in the Columbus area in a larger scale test.

While the use of friction measuring units will create a more objective means of determining level of service, the few friction testers cannot cover the entire state on a continuous basis, so an alternative objective measure is required. One source of statewide data that is being implemented is a statewide Road Weather Information System (RWIS) network. RWIS has already been deployed in Districts 2, 6, and 12, and the present expansion will cover the rest of the state [4]. The initial deployment consisted of systems manufactured by Surface Systems Inc. (SSI), and the expansion consists of pavement sensors manufactured by Nu Metrics with weather sensors manufactured by Vaisala. All of the systems report basic weather data such as air temperature, humidity, and precipitation as well as pavement

condition data reported by pavement sensors. The pavement data include road surface temperature and wet/dry status. The Nu Metrics sensors also report traffic volume and average speed data. Speed and volume data can also be obtained from induction loops that have been installed around the state, particularly in urban areas. However, it is not known if the loops have a sufficiently small time resolution (15 minutes or less) to be used in this study. If these loops cannot collect traffic data at a fine enough time resolution, all sites will be at Nu Metrics installations.

Lee and Ran [1] did a pilot study to measure the potential of using the speed recovery duration as a winter maintenance performance measure. The objective of the study was to develop a winter maintenance procedure using the speed data obtained from automatic traffic recorders. The snow event duration and the maximum speed reduction were used to describe the "vehicle speed reduction". They found that the speed recovery duration doesn't have any direct relationship between weather factors of a snow event like surface temperature, amount of snow etc.Therefore a method of defining the severity of snow event using the "vehicle speed reduction" in a snow event was developed using a regression model. Extensive research was proposed for better calibration of the regression model and use of a bigger sample size to come up with a procedure to be used in the field by state and government agencies for winter maintenance operations.

Georg Abay, Rapp Trans AG Zurich, Switzerland [2] studied the effects of the pros and cons of the road winter services in Switzerland. The investigation was done based on the principle proposed by German authors Durth, Hanke and Levin (1989).The behavior of the traffic before and after the deployment of the winter maintenance operations were studied at different locations. The traffic data (speed, volume) was collected using automatic counters and the weather conditions were also recorded to see its effects on the traffic behavior. Both freeway and city sites were used in the analysis. It was found in the study that the winter travel speeds increased with more snow plowing, salting but the cost of the operations increased considerably. The travel speeds were reduced considerably sometimes during the clearing of the road when the traffic volume was high.

It is expected that speed data will provide an indicator of road surface conditions or level of service because most drivers will slow down if they perceive potentially hazardous road conditions, which may be seen as indicative of a low level of service. In the preliminary literature search, no references on the issue of whether drivers will slow down if they perceive hazardous conditions, but such a statement seems intuitively obvious. While drivers of some types of vehicles, e.g. pickup trucks with all wheel drive, generally appear to be driven faster in snow than other types of vehicles in the same conditions, it is still likely that the drivers of all-wheel drive vehicles slow down in bad weather or they just may not slow down as much, which may be due to their confidence in their vehicles. Issues such as this are explored in driver surveys later in this report. Since Ohio will have a statewide network of traffic speed and traffic volume detectors, it is anticipated that this network will give winter maintenance management a simple tool for quickly determining level of service statewide. However, in order for this tool to be useful, it needs to be validated. The speed that corresponds to a given level of service needs to be determined.

5. BENEFITS

This study will provide a method by which winter maintenance managers can quickly and confidently determine the level of service from RWIS speed data. This will lead to a more uniform and consistent level of service. It will also help make winter maintenance activities evaluations more comparable across the state.

6. IMPLEMENTATION PLAN

The relationship between speed and level of service can be used to establish speed criteria that can be used to assess level of service for winter maintenance efforts. Speed data can also be incorporated into decision making guidelines for snow and ice operations. It will improve the monitoring and evaluation of winter maintenance operations for compliance and validation. It will help in the review and evaluation of efficiency and effectiveness in meeting the level of service standards.

The use of a new procedure in which wet/slated winter travel speeds were used to define the level of service will require some training by ODOT personnel for its proper use and how it relates to existing level of service methods. Actual adoption of the procedure may require a cultural shift, however the cultural shift already required by the implementation of RWIS [4] should make winter maintenance personnel more willing to accept a new set of objective criteria for level of service determinations. Such criteria will also allow for a more ready agreement between personnel on the level of service.

This procedure should be ready for implementation, however it should be monitored over a few winter seasons by comparing it with the traditional level of service determinations to fully establish confidence in the procedure. It may be best to implement this procedure first in northeast Ohio – Cuyahoga, Summit, and Ashtabula counties, where existing speed measurement sites and major snow storms are most likely. It should be noted that a full statewide implementation of speed as a level of service indicator will require filling in holes in the speed data collection network. These are in northwest Ohio, where old RWIS installations lacking speed measurements are prevalent and no new installations are planned, and southeast Ohio, where relatively few sites have been installed as there is less snow and less traffic in this region.

Without further research, the number of sensors needed cannot be fully determined. In a previous study on RWIS for the state [4], the researchers recommended 14 additional RWIS stations as a minimal but adequate deployment. ODOT's present plan to install over 40 seems more than adequate from a weather monitoring point of view, and it is initially expected that this number will be adequate, particularly when augmented by existing inductive loops and weigh-in-motion stations. However, as stated in the previous paragraph, it may be desired to plug a few holes in the northwest and southeast parts of Ohio's speed measurement network.

Implementation of the procedure will likely require finer time resolution of speed data than ODOT generally collects from its ATR sites – speed will need to be averaged and reported over ten or fifteen minute intervals – faster than the changes in winter weather.

4. WINTER MAINTENANCE DRIVER SURVEY

According to ODOT, during a winter storm event, the level of service measures the efficiency and effectiveness of anti-icing measures taken to counter it. Level of service is a subjective estimate of road surface conditions. Currently the road slipperiness and surface conditions are estimated subjectively through visual inspections by field personnel and input from motorists. Objective surface condition criteria would help enormously to create and maintain uniform pavement surface condition standards across multiple jurisdictions. The RWIS sensors installed statewide provide information pertaining to traffic speed and volume data as well as other weather information. Can this RWIS data, particularly the speed data, be used to objectively determine level of service? Human factors may also be considered in making an objective determination of level of service. Any objective determination of level of service can be validated by comparing to results of present subjective methods.

The above question can be answered and evaluated by conducting a driver survey. As most drivers reduce their speed upon perceiving potentially hazardous road conditions, the speed data obtained from RWIS can be correlated to these results. It is expected that the survey results will provide the necessary feedback of road surface conditions which will lead to a more uniform and consistent level of service and thus help in comparing winter maintenance operations across the state.

5. OBJECTIVE OF THE SURVEY

The aim of this survey is to provide ODOT with a more reliable and consistent means of describing and monitoring winter road conditions and determining when to undertake winter maintenance operations by looking at the RWIS speed data. The primary purpose was to evaluate the travel speed and possibly volume as indicators of road conditions during a winter weather event and establish the relationship between travel speed and RWIS weather data to drivers' comfort level and perceived level of service by the Ohio motorists. It also serves the purpose of assessing the road conditions during winter storms and help in improving ODOT's maintenance of the roads by reducing costs or increasing the level of service. The survey was carried out by using a questionnaire shown on the next page and the responses were analyzed to develop a procedure to determine the level of service.

Ohio Department of Transportation Winter Maintenance Driver Survey

OHIO DEPARTMENT OF TRANSPORTATION WINTER MAINTENANCE DRIVER SURVEY

Conducted by the Human Factors and Ergonomics Laboratory of the Ohio Research Institute for Transportation and the Environment at Ohio University

_____Westbound on I76 _____Southbound on I 271 Date: _____

1. Arrival time: _____(AM/PM) ___Daylight ___Dark/Nighttime ___Dawn ___Dusk
2. Specify your gender:_____Male _____Female
3. How many years have you been driving? _____
4. How frequently do you drive this stretch of road? _____Daily _____More than once per week _____About once per week _____ A few times a month _____ Rarely
5. What kind of vehicle are you driving?
   _____Automobile/van _____SUV _____Pick-up _____Large truck _____Tractor-trailer _____ Other (describe)_____
6. Did you drive using:
   _____Two wheel drive (front or rear) _____Four-wheel drive (in use)
7. Did you have your headlights on? _____Yes_____No

8.In which lane did you travel on this freeway for the last few miles or so?
_____Mostly in the **right lane** _____Mostly in the **left or passing lane**

9.At what speed did you drive most of the time during the last few miles or so?
_____About the speed limit
_____Slightly below the speed limit (5-10 mph below)
_____Considerably below the speed limit (10-20 mph below)
_____Very slowly (more than 20 mph below the speed limit)

10.If you drove below the speed limit please rank the following factors that you think reduced your driving speed. Mark 1 for the most important factor, 2 for second most important, etc. If a factor did not impact your driving, do not mark it.
_____The traffic around you (in front, in back)
_____The visibility conditions due to falling snow, freezing rain, or other precipitation.
_____The visibility conditions due to blowing snow
_____The visibility conditions due to fog
_____The road surface conditions, mainly snow on road
_____The road surface conditions, mainly icy and slippery road surface
_____Activity near road such as construction or law enforcement
_____Other (specify)_____
_____None; driving was fine.

11.In your opinion was the road surface for the last few miles or so was:
_____100% clear pavement from edgeline to edgeline

____90% CLEAR PAVEMENT FROM EDGELINE TO EDGELINE

_____80% clear pavement from edgeline to edgeline
_____70% clear pavement from edgeline to edgeline
_____60% or less clear pavement from edgeline to edgeline

12.In your opinion which best describes the current conditions in the lane you drove in the most for the last few miles or so:
_____ clear _____ snow covered _____ snow covered in spots _____ drifted snow
_____ icy _____ icy in spots _____ slush covered _____ blocked

13.If the road had snow cover, were there wheel tracks you could drive on?
_____ No tracks – the road was covered with snow
_____ Wheel tracks in the right (driving) lane only
_____ Wheel tracks in the left (passing) lane only
_____ Wheel tracks in both lanes.

14.In your opinion how would you rate the clearing and treatment of the last few miles or so of this road during this storm?
_____Excellent _____Very Good _____Good _____Fair _____Poor

15.Please rank the following stress factors that you experienced in the last few miles or so of your drive. Mark 1 for the greatest cause of stress, 2 for the next greatest cause, and so on. If a factor did not cause any stress, do not mark it.
_____Not stressful, similar to normal driving
_____Stressful because of falling snow or other precipitation.
_____Stressful because of blowing snow and reduced visibility
_____Stressful because of the traffic around you
_____Stressful because of fog
_____Stressful because of the snow on the highway in your driving lane
_____Stressful because of the icy conditions in your driving lane

16.How difficult was it to drive the last few or so miles of this freeway?
_____Not difficult
_____Just a bit more difficult than under clear and dry conditions
_____Moderately difficult
_____Very difficult

17.How safe do you feel driving the last few or so miles of this freeway?
_____Very safe
_____Just a bit less safe than under clear and dry conditions
_____Moderately safe
_____Not safe

18.What is the estimated percentage of your load?
_____No load. Empty
_____25% of full load or weight

_____50% of full load or weight
_____75% of full load or weight
_____Full load or weight

Do you have any other comments on winter maintenance or road conditions?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Thank You!
We appreciate your participation and help with this evaluation. Have a safe trip and we thank you again!

PROCEDURE FOR DRIVER SURVEY ON I-271 SOUTHBOUND NEAR RICHFIELD (SUMMIT COUNTY) ON DECEMBER 22 2004 (3.15 PM – 9.00 PM) AND DECEMBER 23 2004 (8.45 AM – 1.00 PM)

The main requirement for this survey is a snowstorm in the I-77/I-271 region to conduct a survey. For this, four websites were constantly monitored for forecast weather conditions in the Akron and Cleveland areas. They are Meteorlogix, Scan*Cast, The Weather Channel, and Buckeye Traffic (www.buckeyetraffic.org). The criteria for a winter storm suitable for a survey are storm duration of at least 6 hrs, snowfall of at least 4 inches during the storm, and an air temperature of 32^{o}F or below during the whole storm.

As the weather conditions were favorable for the study, a survey was conducted at Rest Area 04-440 on I-271 Southbound near Richfield in Summit County on December 22 and 23, 2004. Figure 1 shows the map where the survey was conducted. Cleveland and Akron were the nearest stations where the weather data can be obtained. The persons conducting the survey wore an "Ohio University" T-shirt to identify the person conducting the survey as associated with Ohio University. At the rest area a table and two chairs were provided for the persons conducting the survey and two more chairs for the persons responding to the survey. There were about 300 survey forms for the location during the winter storm event. In the front and on both sides of the table, signs were attached reading "Ohio Department of Transportation Winter Maintenance Driver Survey Conducted by Ohio University". Also, an "Ohio University Human Subject Consent" information sheet, shown in Appendix A, was placed on top of the table for the survey participants to review, explaining the study and its risks and benefits. Figure 2 shows the setup for the survey. The rest are was located at 1.582 miles away from the entrance ramp from Brecksville road before the drivers stopped at the rest area.

5.1 Driver Survey Conducted on I-271 Southbound near Richfield (Summit County) On December 22 2004 (3.15 PM – 9.00 PM) and December 23 2004 (8.45 AM – 1.00 PM)

Figure 1: Map Showing Cleveland, Akron and the Rest Area Location where the Survey was conducted.

Figure 2: Setup of the survey at rest area 04-440 on IR- 271 southbound.

The survey was started on December 22, 2004 at 3.15 PM. The survey procedure was to provide the respondent with the questionnaire titled "Ohio Department of Transportation Winter Maintenance Driver Survey", shown earlier in the report, containing a series of questions posed to drivers about their experience driving in the snowstorm. Some respondents filled the forms by themselves while others were interviewed by ORITE personnel.
The survey was conducted until 9.00 PM on December 22, 2004. It began again on December 23 2004 from 8.45 AM and continued until 1.00 PM. On December 22, there were about 95 people coming into the rest area out of which 28 were women and on the 23rd there were around 103 out of which 31 were women. These figures count everyone apparently of driving age entering the rest area building during these times, including passengers and drivers. On the 22nd 52 people responded to the questions, while on the 23rd 40 people answered the survey. The response percentage on the 22nd was 54.7% and on the 23rd it was 38.8%. The average response percentage for both days was 46.5 %.
The frequency of snow plows passing by the rest area was noted. On 12/22/2004, the snow plows passed through the rest area at around 6.27 pm and 8.22 pm and on 12/23/2004, they passed through at around 9.46 am, 11.49 am and 12.42 pm. On the 22nd the frequency was lower than on the 23rd.

5.2 Speed, Weather and Vehicle Count Data from RWIS Station No. 68

RWIS data (Station No – 68) were obtained from ODOT and graphs are plotted for average speed of vehicles, surface temperature and vehicle count on I-271 Southbound for days beginning from December 20 to December 24, 2004. Figure 3 and Figure 4 show the average

speed of the vehicles over 5 minute intervals passing by the I-271 Southbound road in the driving and passing lanes respectively. It can be observed that the speed of vehicles decreased gradually from around 70 mph to 30 mph from about 9.30 AM on December 22. The official speed limit on I-271 southbound was 65 mph. It should be noted that most of the data points at zero were blank in the data file indicating data from the sensor were not reported.

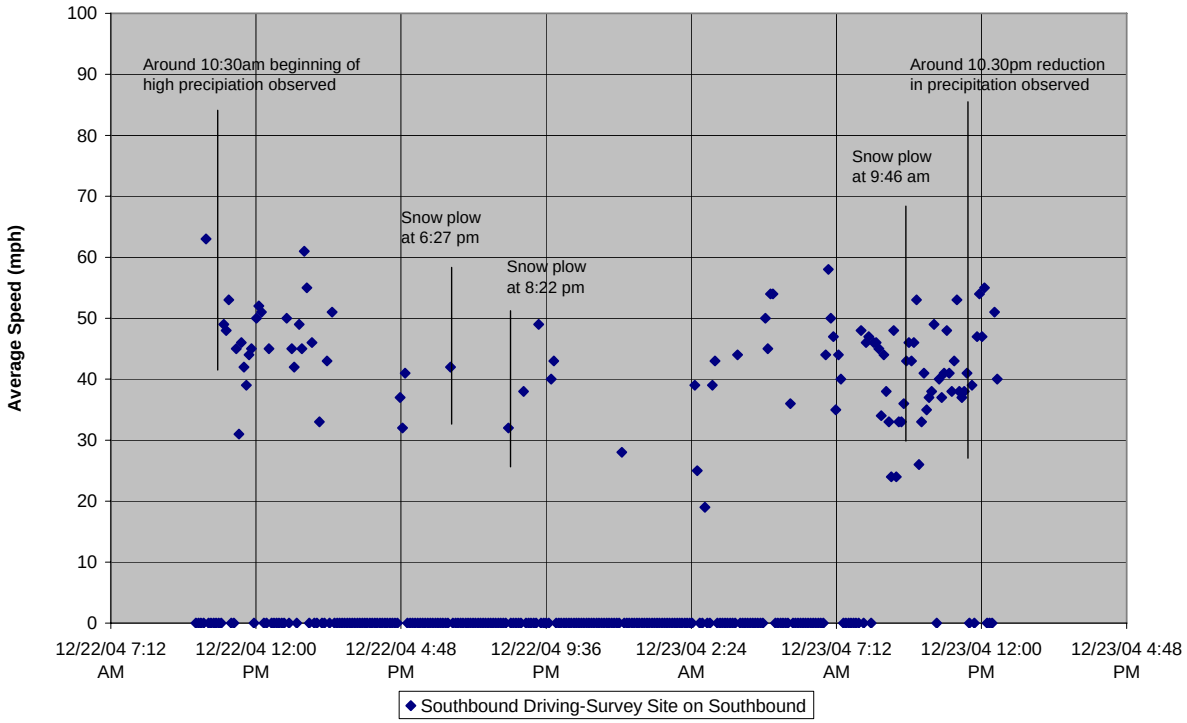

Figure 3: Plot of average speed of vehicles from RWIS data (station no. 68) for I-271 southbound driving lane.

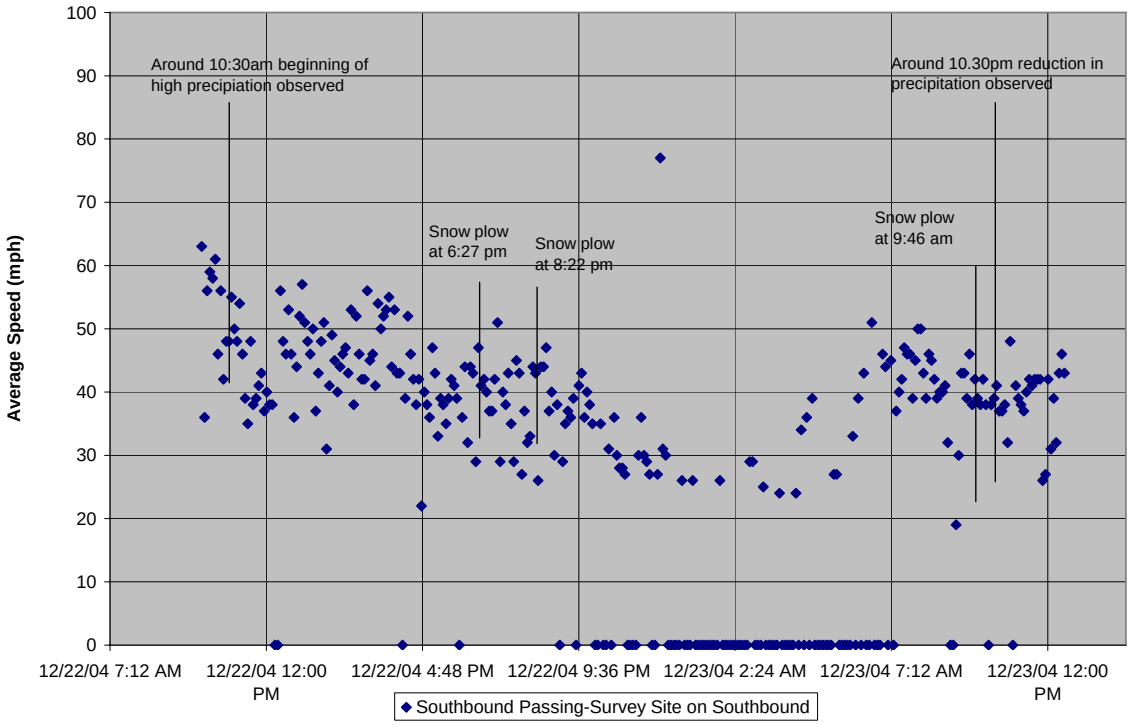

Figure 4: Plot of average speed of vehicles from RWIS data (station no. 68) for I-271 southbound passing lane.

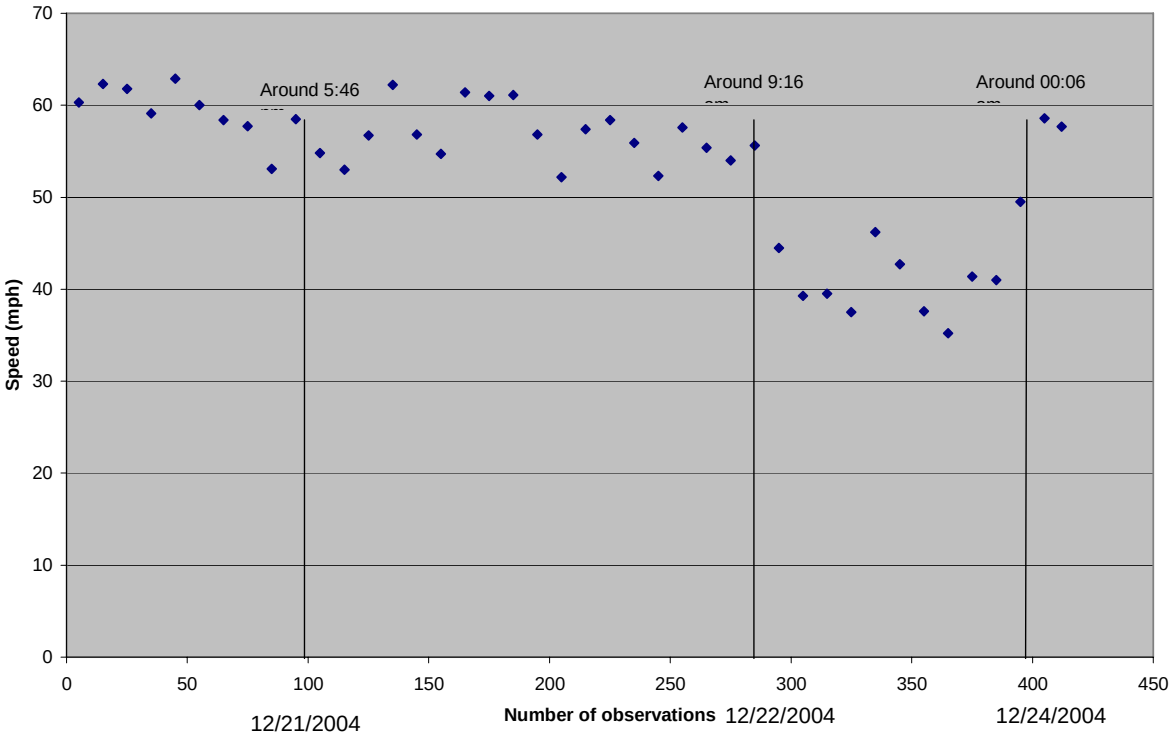

Figure 5: Plot of average speed of vehicles from RWIS data (station no. 68) for I-271 southbound driving lane.

Figure 5 and Figure 6 show the redrawn plot of average speed of vehicles from the RWIS data for I-271 south bound driving and passing lanes. All the zero values from the RWIS data were taken out and new average plots were obtained by taking average of ten consecutive speed values.

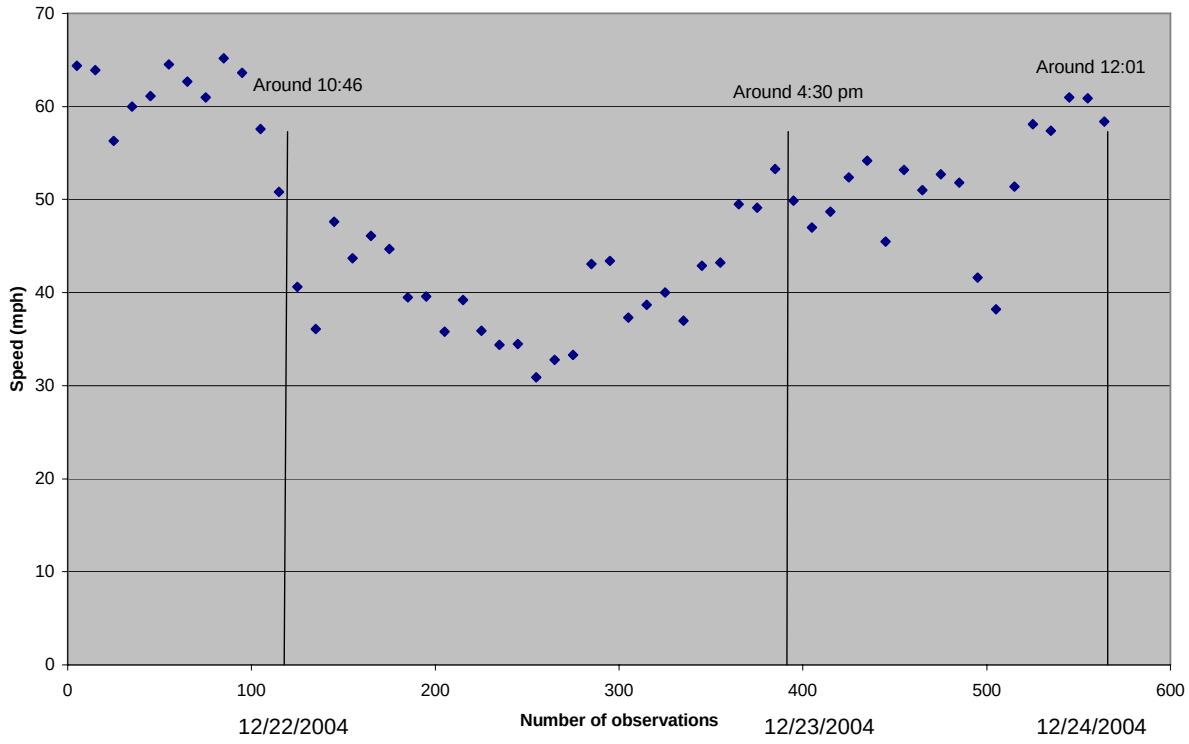

Figure 6: Plot of average speed of vehicles from RWIS data (station no. 68) for I-271 southbound passing lane.

Figure 7 and Figure 8 show the surface temperature graphs for driving and passing lanes respectively. From the surface temperature graphs it can be observed that the temperature was at or below 32ºF during the period the survey was conducted. The horizontal lines in Figure 7 and to a lesser extent in Figure 8 indicate times when the sensor was "stuck" and not actively reporting updated data.

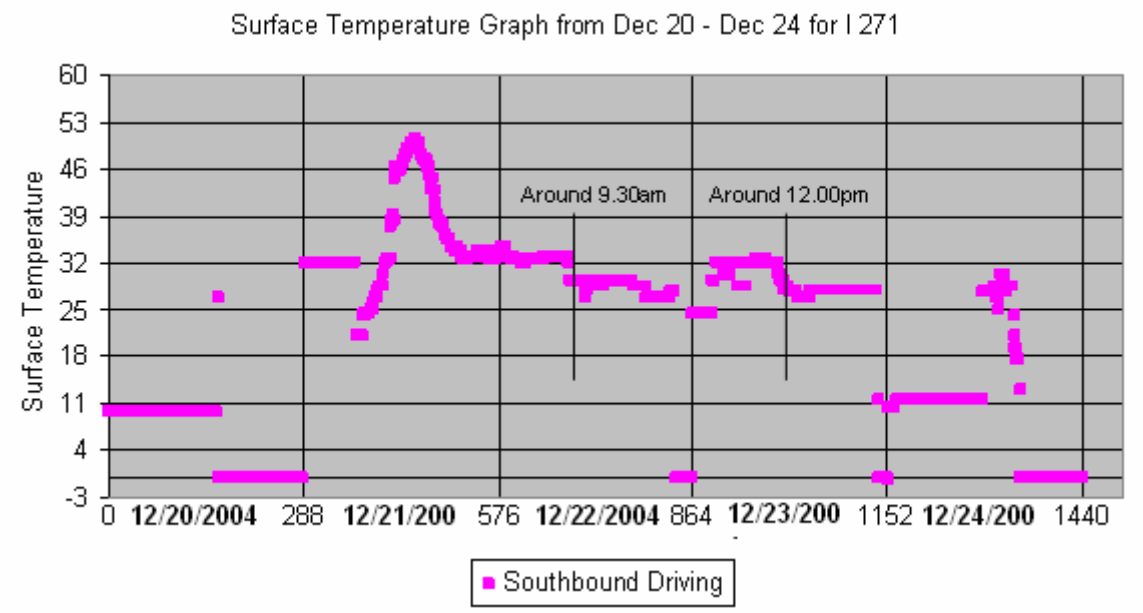

Figure 7: Plot of surface temperature from RWIS data (station no. 68) for I-271 southbound driving lane.

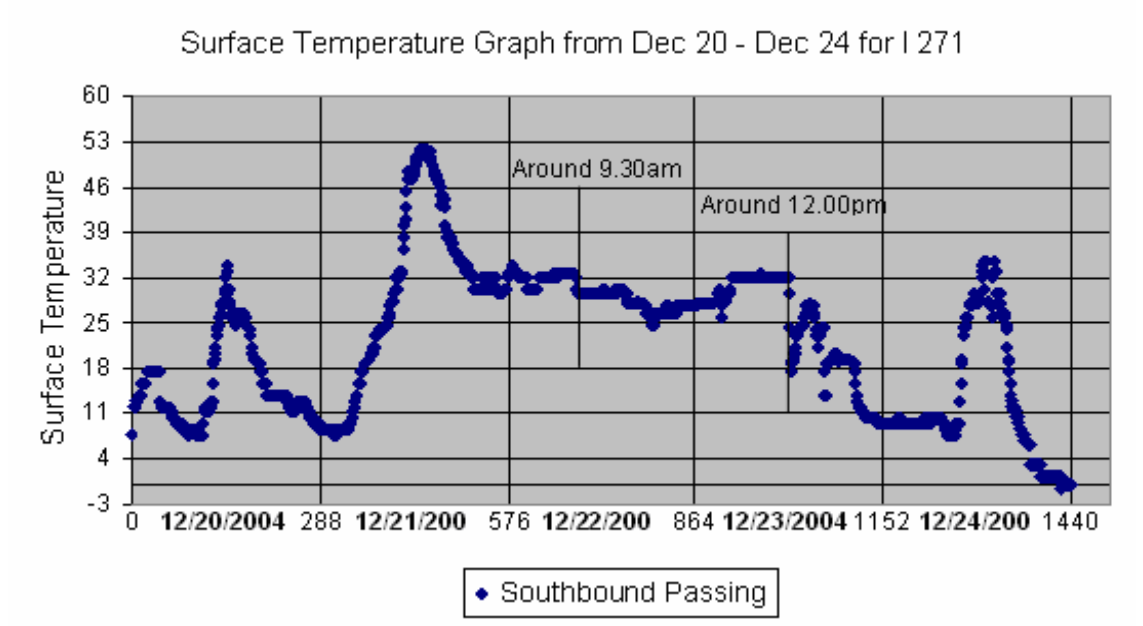

Figure 8: Plot of surface temperature from RWIS data (station no. 68) for I-271 southbound passing lane.

Figure 9 shows the plot of the air temperature from the data obtained from RWIS station (No. 68) for I-271 site. The temperature fell below 32ºF from around 9.00 am on December 22 and continued until early morning of 23rd.

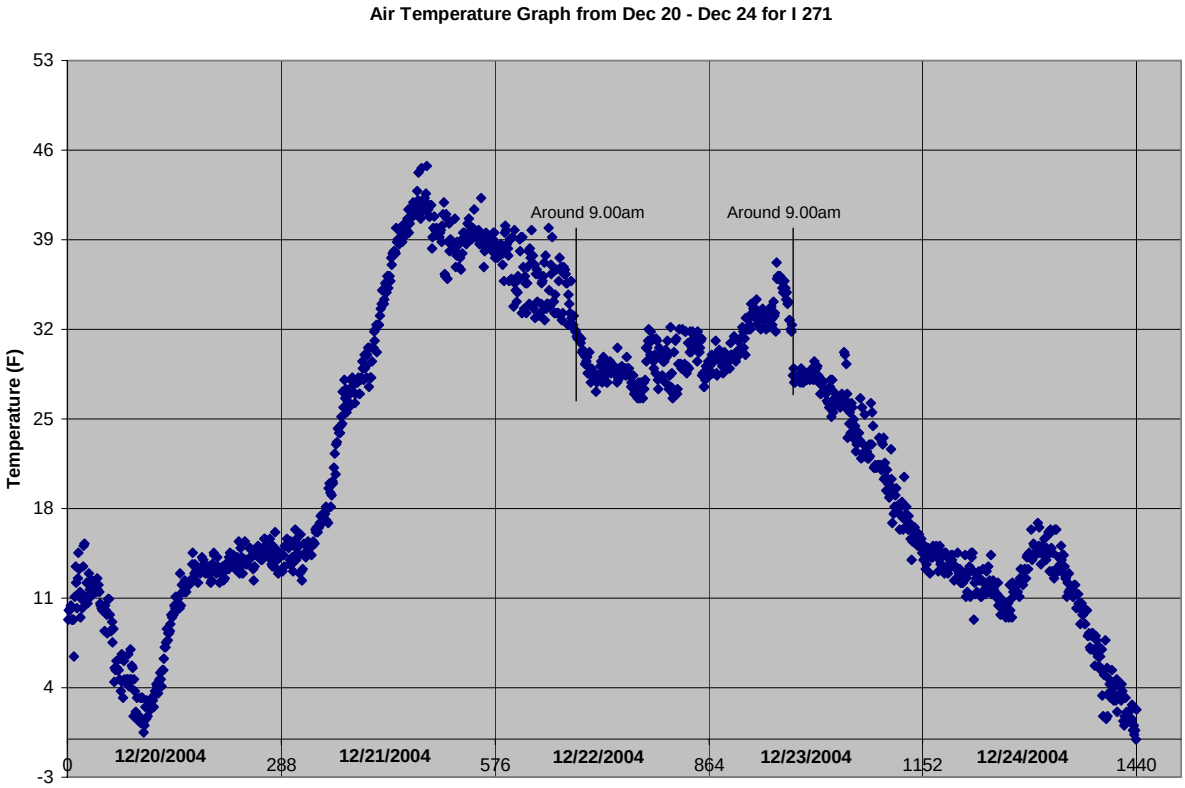

Figure 9: Plot of air temperature from RWIS data (station no. 68) for I-271.

A plot of the number of vehicles on I-271 Southbound from 20 to 24 December was done. Figure 10 shows when a sensor is "stuck", it continues to continue vehicles and reports the accumulated total when it is able to communicate with the RPU again, resulting in anomalously high vehicle counts following a series of 0 values for count and speed. In Figure 11 all counts above 300 have been discarded, but even this limit of one vehicle every second seems high considering the weather conditions. Thus is Figure 12 and Figure 13, the same data are re-plotted discarding all counts above 10, or one vehicle every 3 seconds, for driving and passing lanes respectively. In the passing lane, a depression in the count from a maximum period count of about 50-60 before to a value less than 30 can be clearly seen, and thus probably reflects the weather conditions. Driving conditions improved later on the 24th, but traffic volume still peaks at about two-third of the normal value.

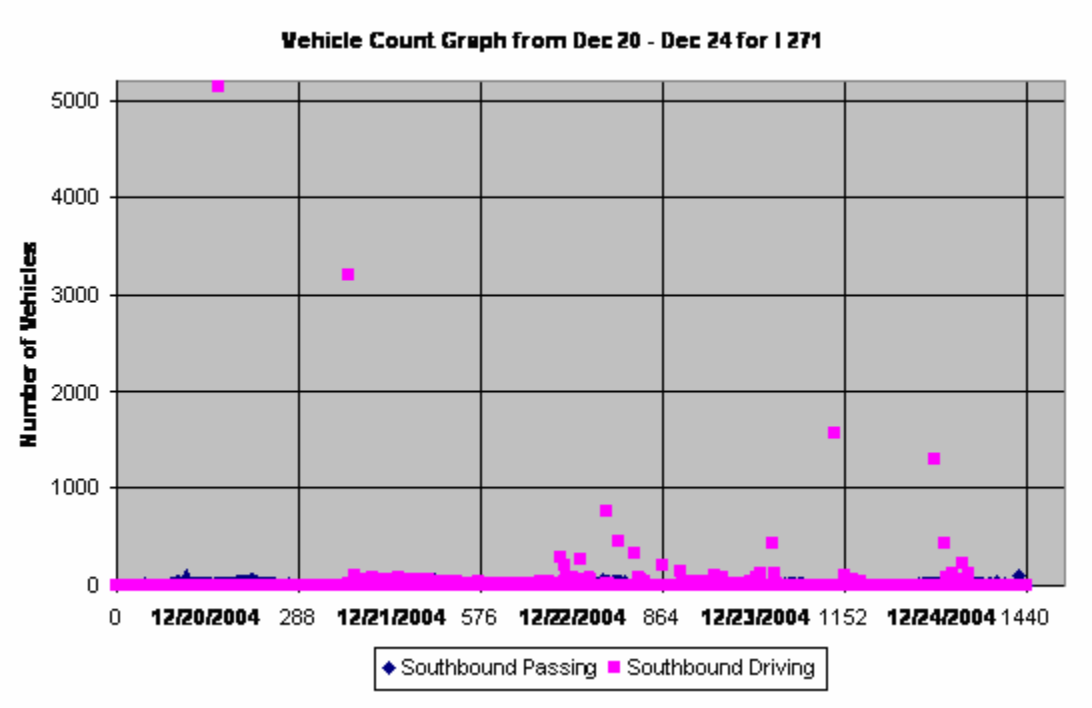

Figure 10: Plot of the number of vehicles from RWIS data (station no. 68).

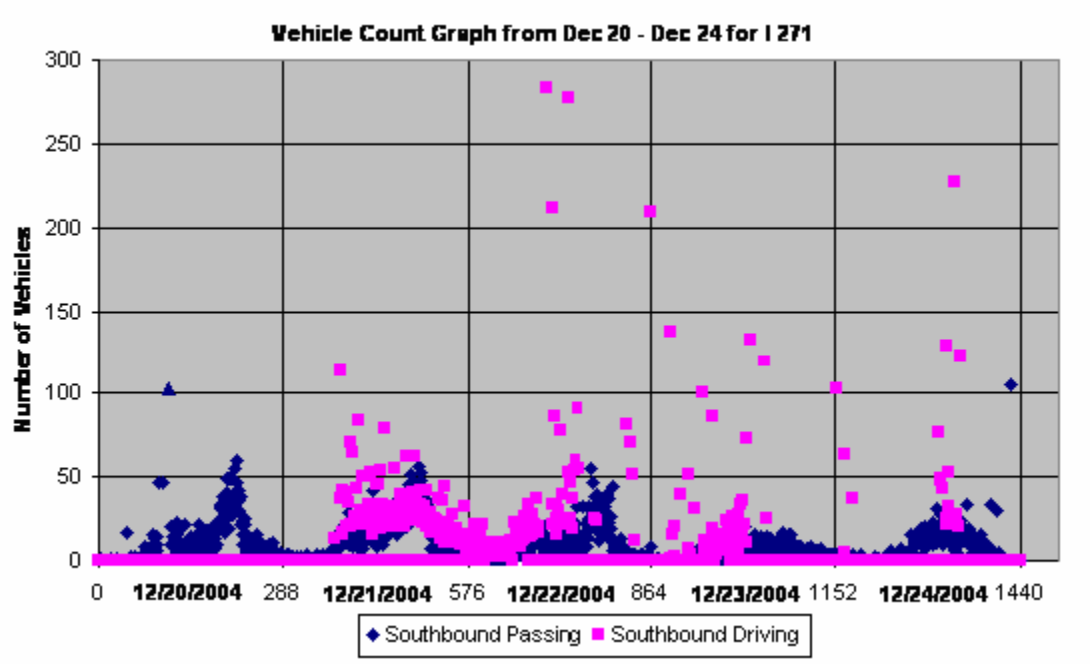

Figure 11: Redrawn plot of the number of vehicles from RWIS data (station no. 68) with maximum period count = 300.

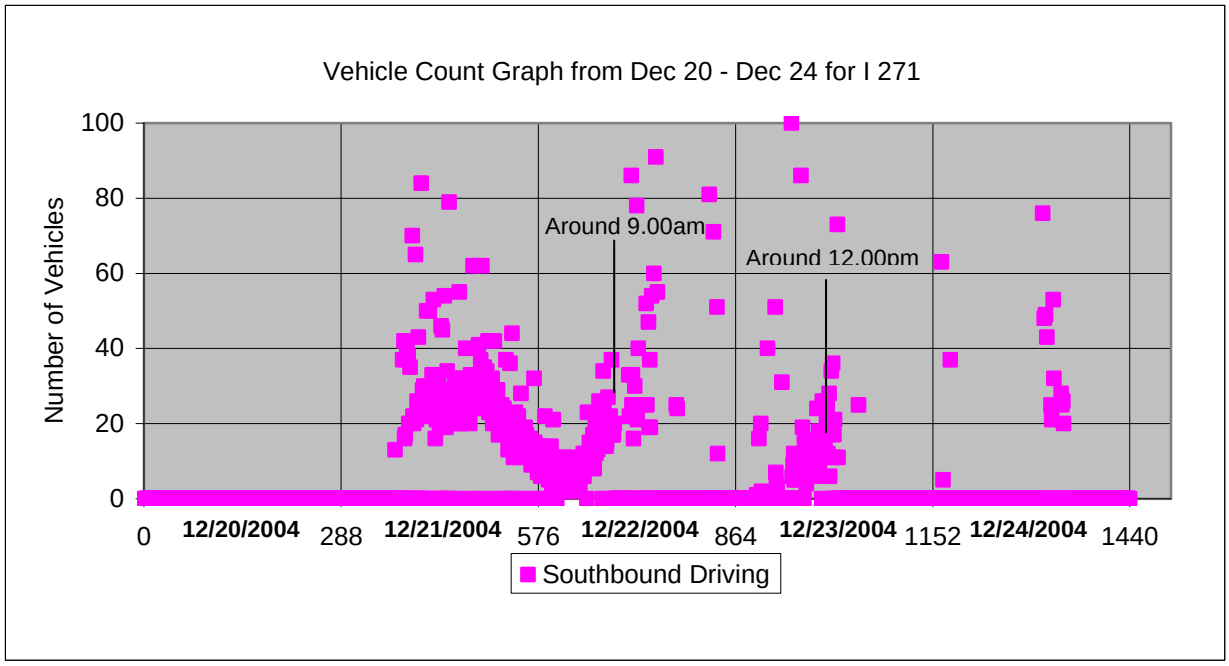

Figure 12: Redrawn plot of the number of vehicles from RWIS data (station no. 68) for I-271 southbound driving lane with maximum period count = 100.

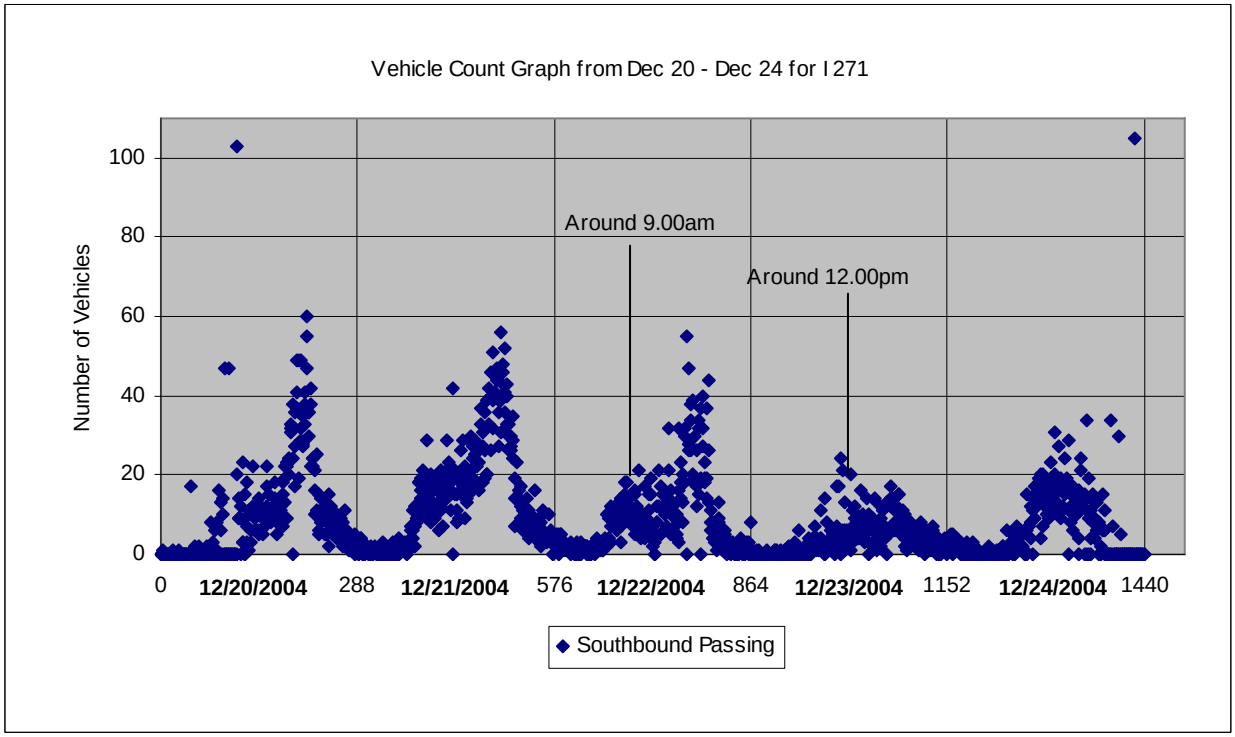

Figure 13 : Redrawn plot of the number of vehicles from RWIS data (station no. 68) for I-271 southbound passing lane with maximum period count = 100.

5.3 Weather Data from National Climatic Data Center

Weather data starting from December 19 to December 24 were viewed online from the National Climatic Data Center website (http://www.ncdc.noaa.gov/). The data are unedited surface weather observations daily observations (10B form). The two closest locations where the data from the website can be observed were Akron Fulton International Airport and Cleveland Hopkins International Airport stations. Figure 14 and Figure 15 show the hourly precipitation amount (water equivalent) at stations located in Akron and Cleveland respectively between the19 and 24 December, 2004. It was noted that the considerable amount of snowfall and other precipitation prevailed from afternoon of the 22nd to the afternoon of the 23rd. On 22nd at the station in Akron the total snowfall was recorded at 0.56 inches (water equivalent) and on 23rd it was 1.18 inches. In the Cleveland Hopkins International Airport station, there were a total of 0.7 inches (water equivalent) on 22nd and 1.13 inches on 23rd.The RWIS precipitation data for station 68 is tabulated in Appendix c of the report.
The conversion of inches of water into inches of snow is highly variable and dependent on a number of factors as indicated in Snow Rain Equivalents (http://www.weatherwise.org/qr/qry.snowrainequiv.html/) and Snow (http://www.acsu.buffalo.edu/~insrisg/nature/nw99/snow.html/) articles. In some cases 5-10 inches of heavy snow converts to an inch of water while at the other extreme 30 inches of very light snow converts to only 1 inch of water.

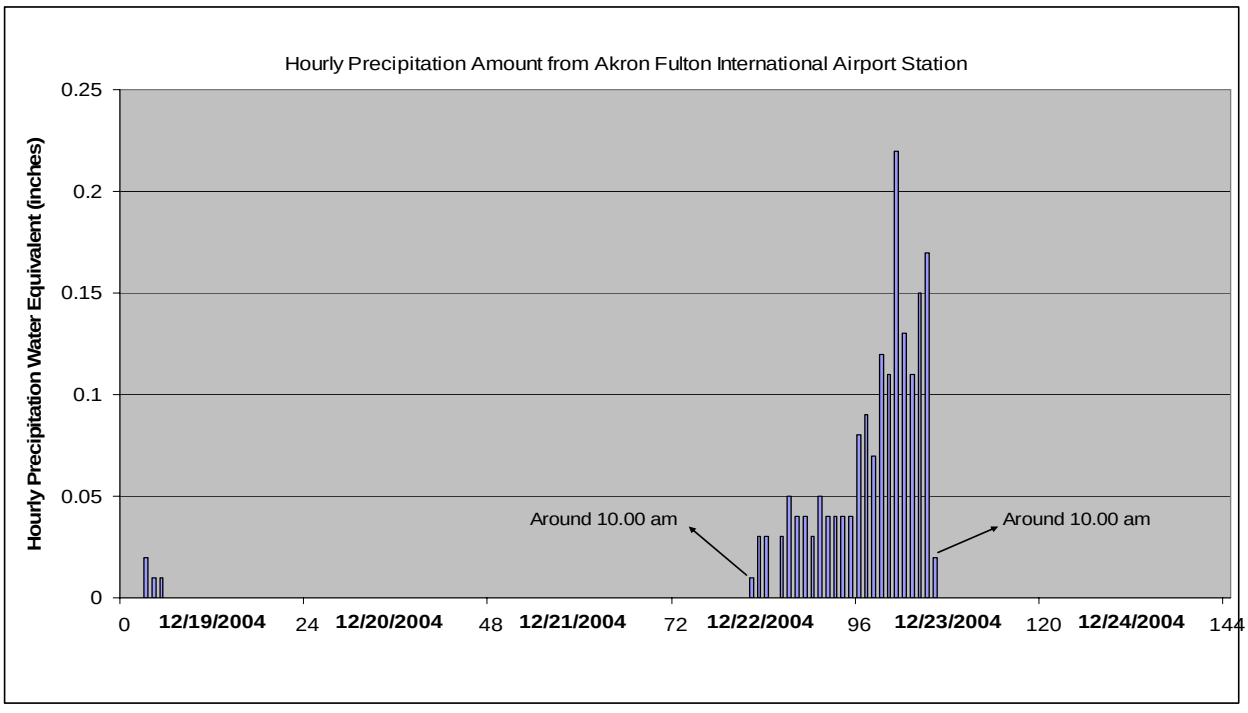

Figure 14: Hourly precipitation amount at station located In Akron.

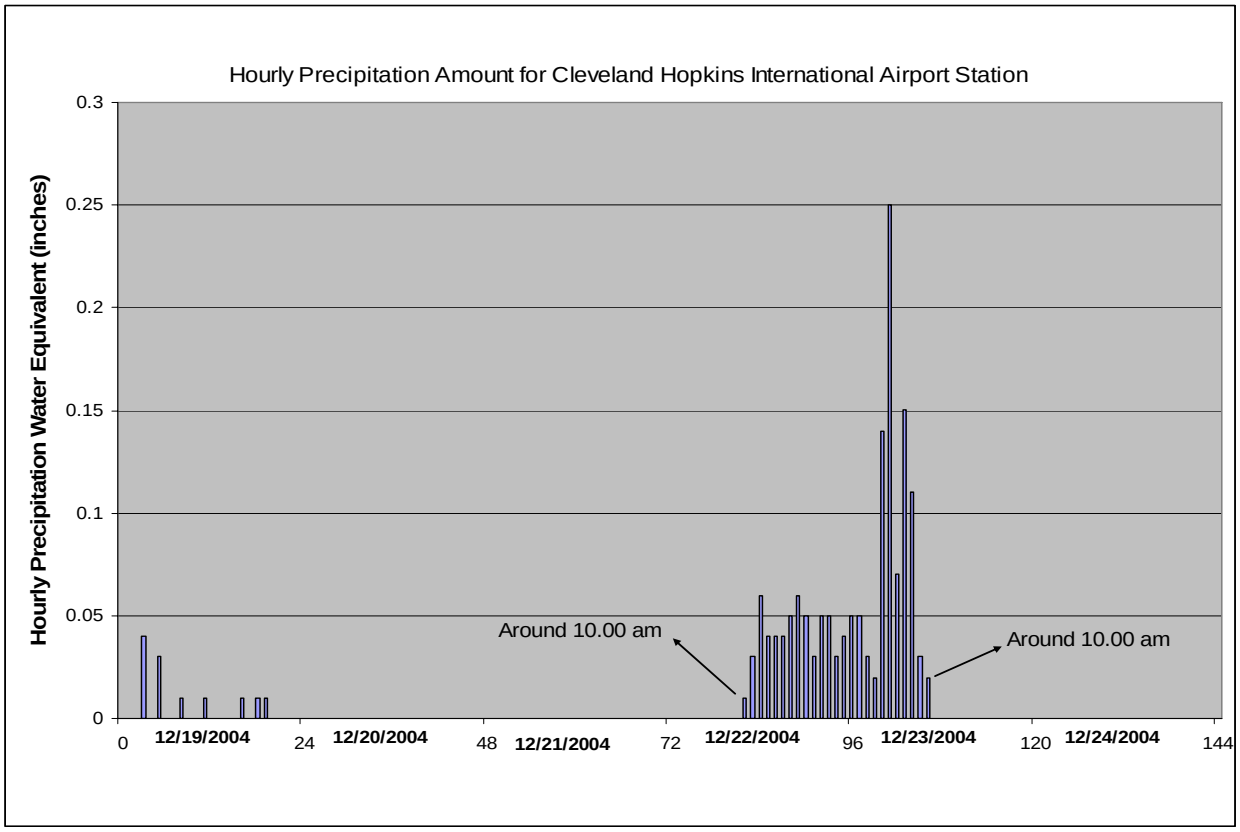

Figure 15: Hourly precipitation amount at station located in Cleveland.

5.4 Pictures from I-271 Southbound on December 22, 2004

Figure 16, Figure 17, Figure 18, and Figure 19 show the pictures taken on I-271 on December 22, 2004. It can be seen that most of the road was covered with snow. There were wheel tracks on both lanes.

Figure 16 : Picture documenting typical road condition on freeway entrance ramp to I-271 on December 22, 2004. The road is covered with snow.

Figure 17: **Picture documenting typical road condition on main line at I-271 on December 22, 2004. The road is covered with snow.**

Figure 18: Picture documenting typical road condition taken on freeway entrance ramp at I-271 on December 22, 2004. The road is covered with snow.

Figure 19: Picture documenting typical road condition taken on main line on I-271 on December 22, 2004. The road is covered with snow.

5.5 Pictures from I-271 Southbound on December 23, 2004

Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, Figure 25 show the pictures taken on December 23 on I-271. Figure 26 shows a snow measurement taken at the rest area at about 10.00 AM on the 23rd. The snow depth was around 17 inches (43 cm). At 8.24 AM on December 23, it was observed that the roads were covered with chunks of ice and slush and that tracks were visible. The visibility range was about a quarter mile and the driving speed was about 30 mph (48 km/hr).

Figure 20: Picture documenting typical road condition taken on main line of I-271 on December 23, 2004. The road is covered with snow, ice, and slush.

Figure 21: Picture documenting typical road condition taken on the main line of I-271 on December 23, 2004. The road is covered with snow, ice, and slush.

Figure 22: Picture documenting typical road condition taken on main line at I-271 on December 23, 2004. The road is covered with snow, ice, and slush.

Figure 23: Picture documenting typical road condition at the rest area on I-271 where the survey was conducted on December 23, 2004. The road is covered with snow, ice, and slush.

Figure 24: Picture documenting typical road condition taken on main line at I-271 site on December 23, 2004. The road is covered with snow, ice, and slush.

Figure 25: Picture documenting typical road condition taken on and exit lane off I-271 on December 23, 2004. The road is covered with snow, ice, and slush.

Figure 26: Picture showing the 17” (43 cm) of snow cover at the rest area on December 23, 2004.

6. RESULTS FOR SURVEY ON I-271

The results of the survey are given in this section. For each question, the number of respondents who answered is given for each day along with their percentage. A column chart is drawn to graphically show the results and compare both days. The survey results are first given for car and truck drivers together, and then separate.

Question 1

The first question the respondents were asked was at what time they arrived to the rest area. On December 22, 9 people arrived at daylight, 12 during dusk and 31 at night. On December 23, all the 40 people were surveyed during daylight hours. Table 1 shows the number of people surveyed during each phase on both days.
Table 2 shows the number of car and truck drivers surveyed during each phase on both days.

Table 1. Number of People Surveyed at Different Periods.

		# Respondents	
Date		**12/22/2004**	**12/23/2004**
Period of Time	**Day light**	9	40
	Dark/Night time	31	0
	Dawn	0	0
	Dusk	12	0

Table 2. Number of Car and Truck Drivers Surveyed at Different Periods.

		# Respondents			
Dates		**12/22/2004**		**12/23/2004**	
Vehicle Type		**Cars**	**Trucks**	**Cars**	**Trucks**
Period of Time	**Day light**	6	3	30	10
	Dark/Night time	21	10	0	0
	Dawn	0	0	0	0
	Dusk	9	3	0	0

Question 2

Question 2 asked the gender of the respondent. Table 3 shows the number of respondents and percentages of both male and female on both days. Figure 27 shows their percentages graphically. Table 4 shows the number of respondents and percentages of both male and female car and truck drivers on both days. Figure 28 shows their percentages graphically. It can be observed that on both of the days the truck drivers were all male.

Table 3. Number and Percentage of Male and Female Respondents.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
Gender	Male	43	82.69%	36	90.00%
	Female	9	17.31%	4	10.00%

Table 4. Number and Percentage of Car and Truck Drivers according to Gender of the Respondents.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
Gender	Male	27	75.00%	16	100.00%	26	86.67%	10	100.00%
	Female	9	25.00%	0	0.00%	4	13.33%	0	0.00%

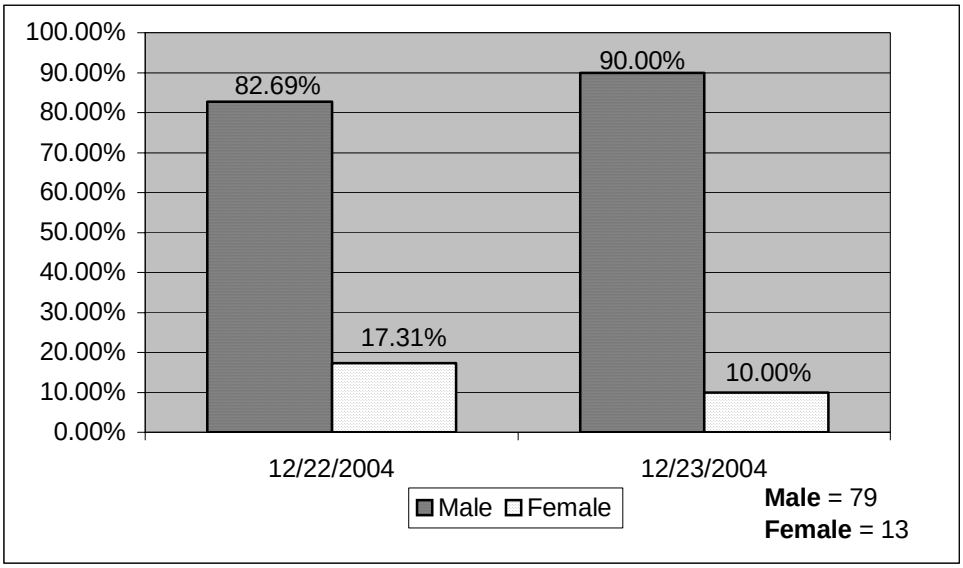

Figure 27: Response Percentage of Male and Female.

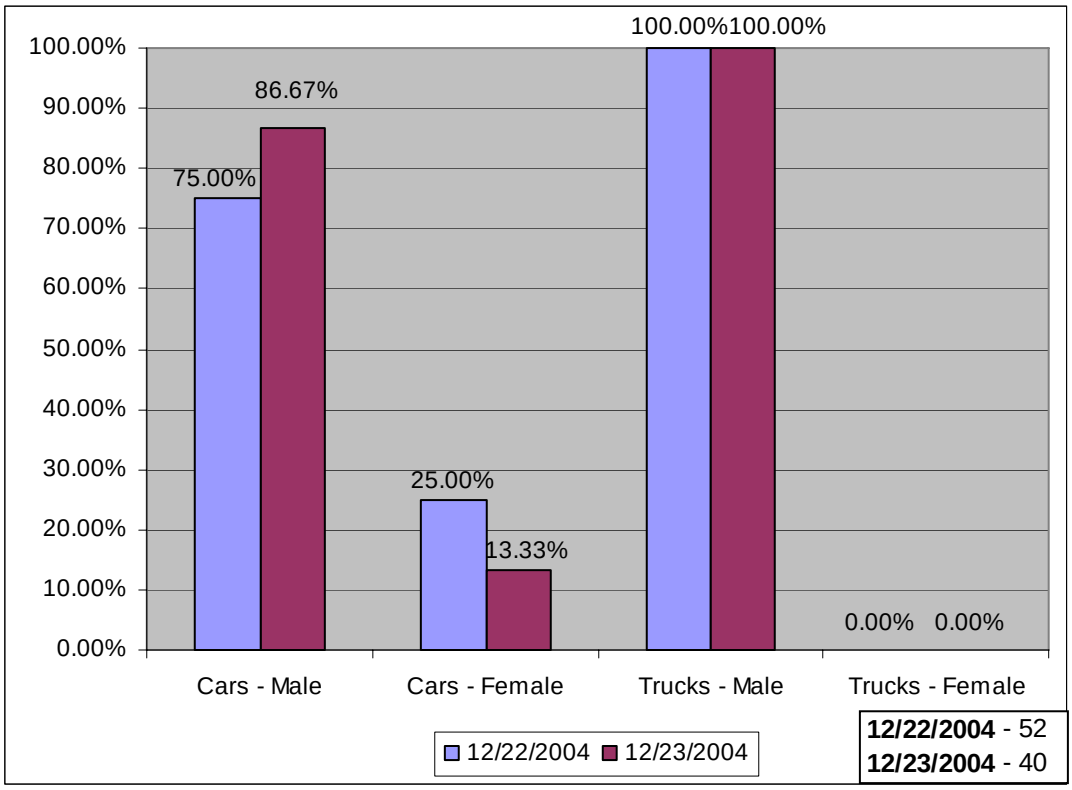

Figure 28: Response Percentage of Male and Female Car and Truck Drivers.

Question 3

The number of years of experience the driver had was asked in the third question. It was found that the average number of years is 26 for the survey on December 22 and 25 years on December 23. The minimum, maximum, mode, median, and standard deviation are given in Table 5. Figure 29 is a frequency graph of the number of drivers and their related experience. Grouping drivers by decades of experience, on the 22nd, the largest group drivers surveyed had driving experience between 30 and 40 years, while on the 23rd the largest group had 10 to 20 years driving experience.

It was found that the average driving experience is 29 years for car drivers and 20 years for truck drivers for the survey on December 22 and 28 years for car drivers and 15 years for truck drivers on December 23. The minimum, maximum, mode, median, and standard deviation are given in Table 6. Figure 30 and Figure 31 are frequency graphs of the number of drivers and their related driving experience for car and truck drivers. Grouping drivers by decades of experience, on the 22nd, the largest group drivers surveyed had driving experience between 30 and 40 years, while on the 23rd the largest group had 10 to 20 years driving experience.

Table 5. Statistics of How Many Years the Driver was Driving.

		# Respondents	
Date		**12/22/2004**	**12/23/2004**
How many years have you been driving?	**Total # of Drivers**	52	40
	Minimum	3	1
	Maximum	53	60
	Average	25.94	24.88
	Mode	40	20
	Median	26	24
	Standard Deviation	13	15.83

Table 6. Statistics of How Many Years the Driver was Driving (car and truck drivers separate).

Date		**12/22/2004**		**12/23/2004**	
Vehicle Type		**Cars**	**Trucks**	**Cars**	**Trucks**
How many years have you been driving?	**Minimum**	5	3	1	2.5
	Maximum	53	46	60	41
	Average	28.64	19.88	28.13	15.10
	Mode	35	40	25	10
	Median	30	14.5	25	10
	Standard Deviation	11.96	14.38	15.52	12.36

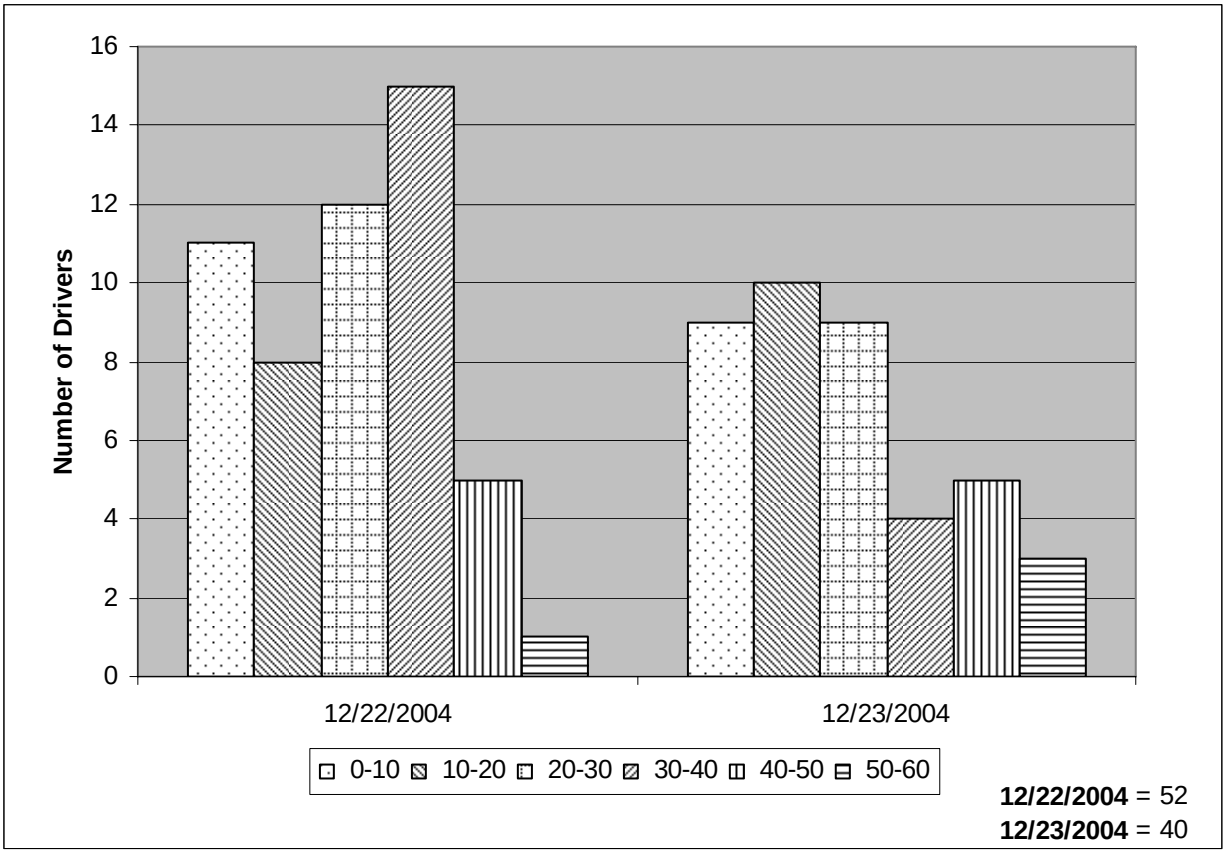

Figure 29: Graph Showing Relation between Number of Drivers and their Experience.

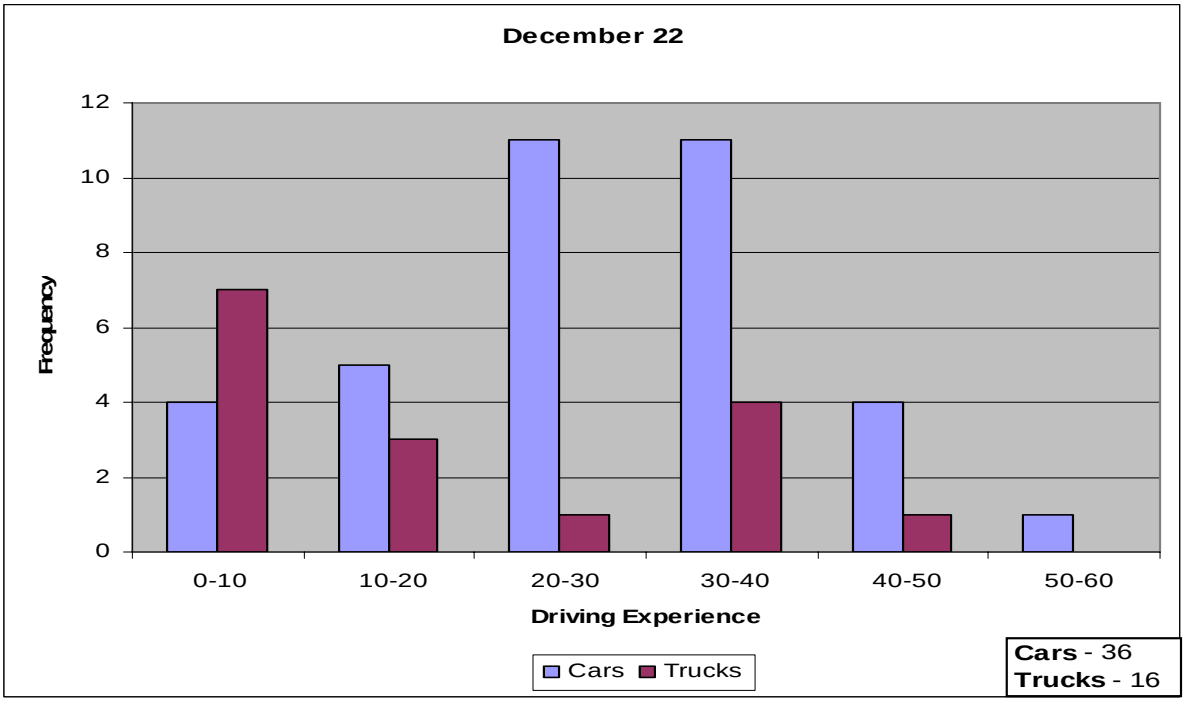

Figure 30: Graph Showing Relation between Number of Car and Truck Drivers and their Driving Experience on December 22, 2004.

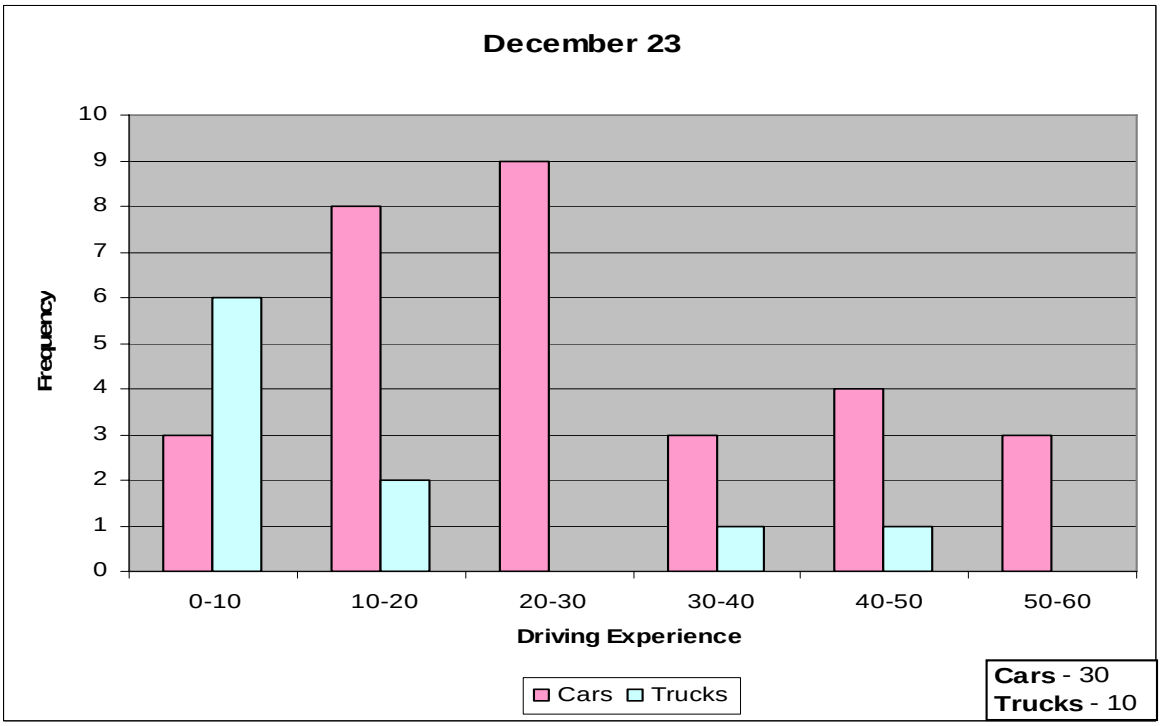

Figure 31: Graph Showing Relation between Number of Car and Truck Drivers and their Driving Experience on December 23, 2004.

Question 4

Question 4 asked how frequently the drivers drove that stretch of Southbound. The plurality of respondents answered that they rarely drove through on the road. These were typically drivers making an annual trip for a Christmas visit. Only 17% on December 22 and 2.5% on December 23 replied that they daily drove Southbound on this portion of I-271. Table 7 and Figure 32 signify the responses in tabular form and graphically respectively. Only 19% of car drivers, 12.5% of truck drivers on December 22 and 3.33% of car drivers on December 23 replied that they daily drove Southbound on this portion of I-271. Table 8 signifies the responses in a tabular form and Figure 33 and Figure 34 show them graphically for December 22 and 23 respectively.

Table 7. Responses for How Frequently Drivers Drove I-271 Southbound.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
How frequently do you drive this stretch of the road?	Daily	9	17.31%	1	2.50%
	More than once per week	4	7.69%	1	2.50%
	About once per week	6	11.54%	5	12.50%
	A few times a month	15	28.85%	13	32.50%
	Rarely	18	34.62%	20	50.00%

Table 8. Responses for How Frequently Car and Truck Drivers Drove I-271 Southbound.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How frequently do you drive this stretch of the road?	Daily	7	19.44%	2	12.50%	1	3.33%	0	0.00%
	More than once per week	3	8.33%	1	6.25%	1	3.33%	0	0.00%
	About once per week	2	5.56%	4	25.00%	2	6.67%	3	30.00%
	A few times a month	8	22.22%	7	43.75%	8	26.67%	5	50.00%
	Rarely	16	44.44%	2	12.50%	18	60.00%	2	20.00%

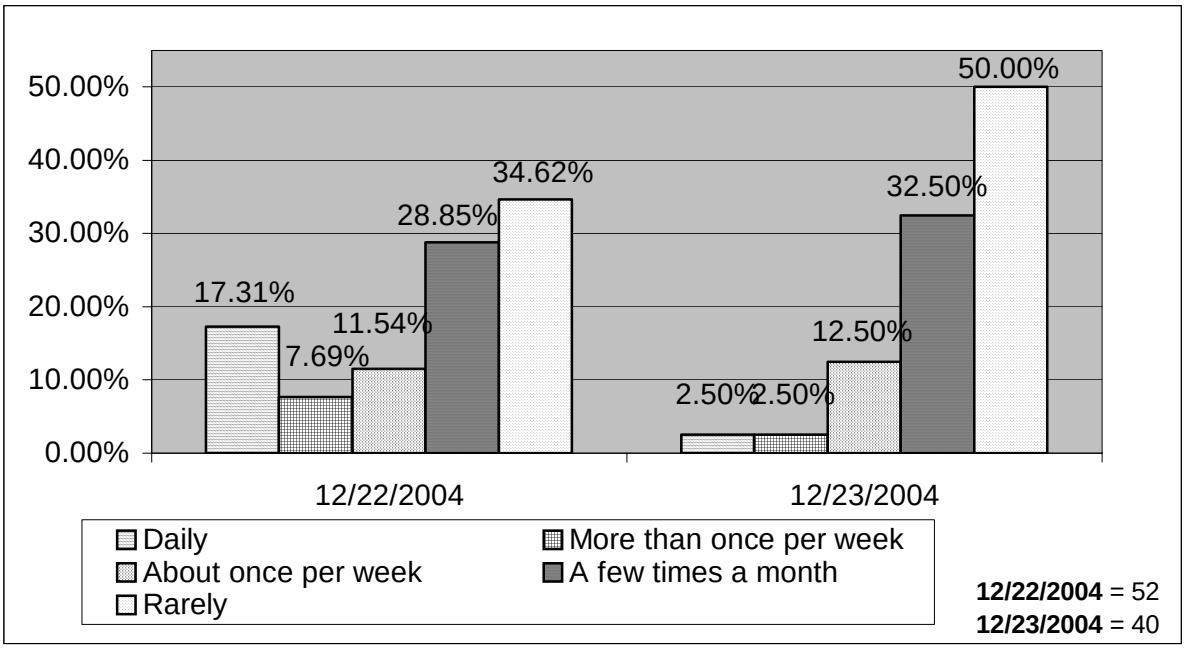

Figure 32: Frequency of People Driving by I-271 Southbound.

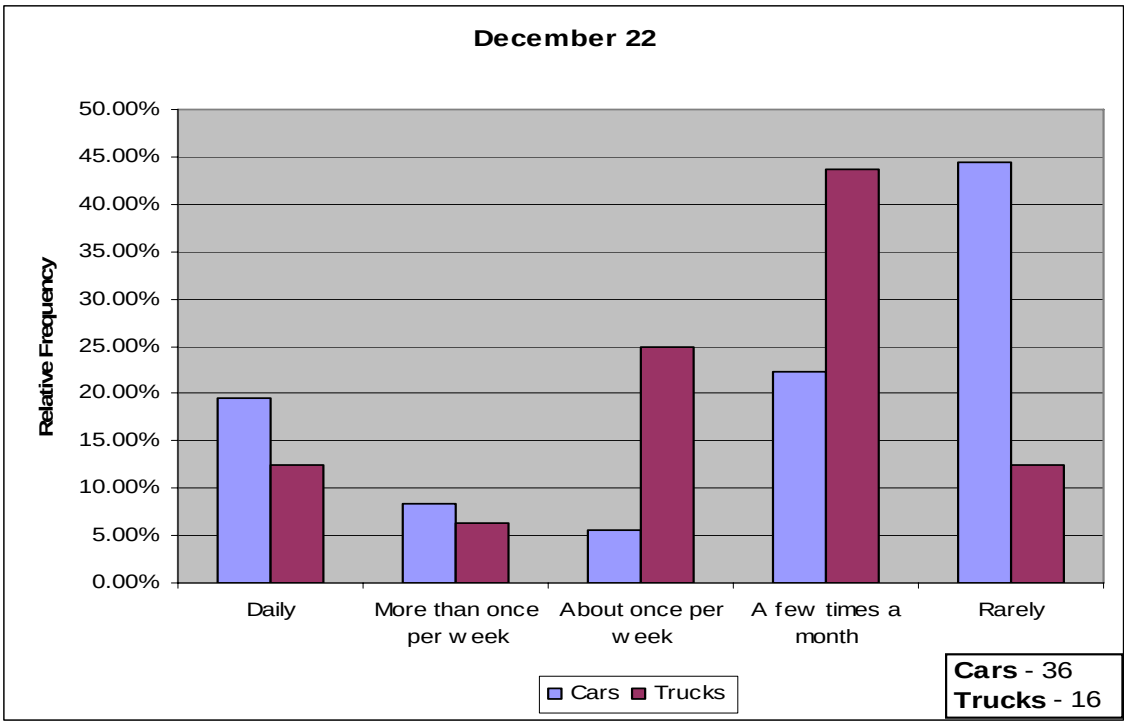

Figure 33: Relative Frequency of Car and Truck Drivers Driving by I-271 Southbound on December 22, 2004.

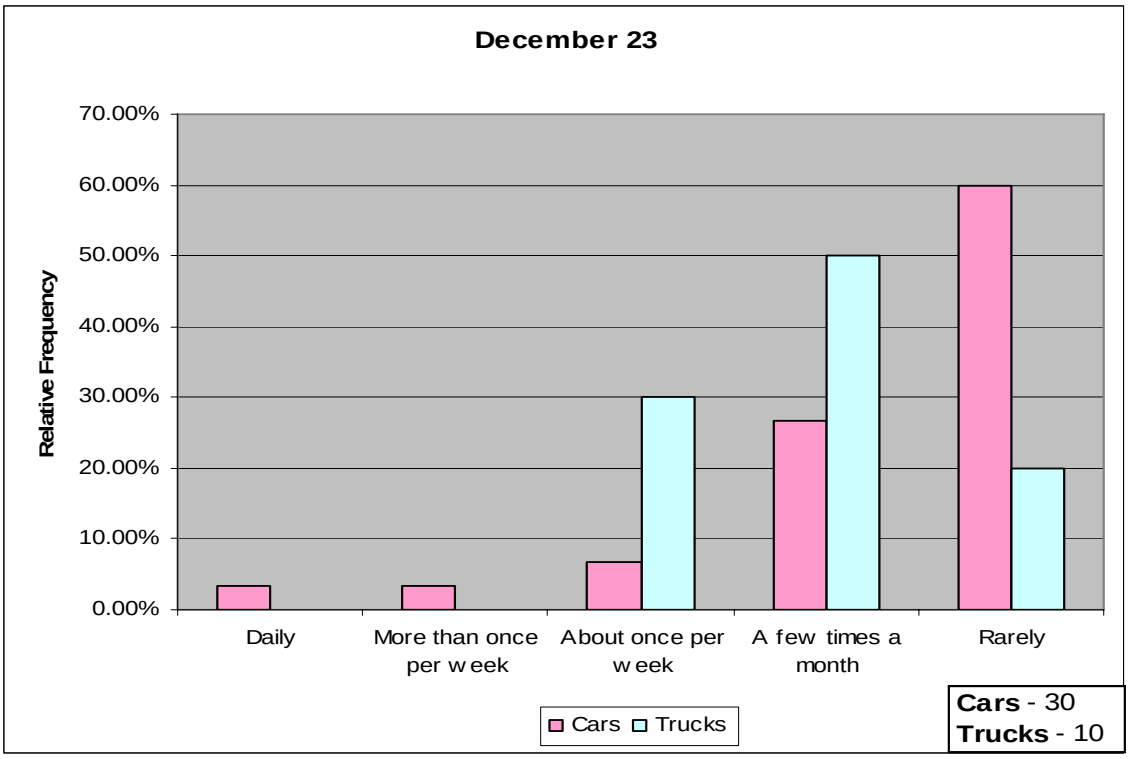

Figure 34: Frequency of Car and Truck Drivers Driving by I-271 Southbound on December 23, 2004.

Question 5

The drivers were asked about the type of vehicle they were driving. Table 9 shows the number of drivers driving a particular type of vehicle. It can be seen that on December 22 69% drove an automobile, van, SUV, or a pick-up truck while 31% drove large truck or a tractor-trailer. On December 23, 75% drove an automobile, van, SUV or pick-up truck while 25% drove large truck or a tractor-trailer. Figure 35 shows the percentage graphically.

Table 10 shows the number of car and truck drivers driving a particular type of vehicle. Out of all the car drivers on December 22 69% drove an automobile/van, 17% drove SUV and 14% drove pick-up truck. 12.5% drove large truck and 87.5% drove tractor-trailer of all the truck drivers on 22 December. On December 23, 63% drove an automobile/van, 30% SUV and 7% drove pick-up truck while all the truck drivers drove a tractor-trailer. Figure 36 and Figure 37 shows the percentages graphically for December 22 and 23.

Table 9. Number and Percentage of People Driving a Particular Type of Vehicle.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
What kind of vehicle are you driving?	Automobile/ Van	25	48.08%	19	47.50%
	SUV	6	11.54%	9	22.50%
	Pick-up	5	9.62%	2	5.00%
	Large truck	2	3.85%	0	0.00%
	Tractor-trailer	14	26.92%	10	25.00%
	Other (describe)	0	0.00%	0	0.00%

Table 10. Number and Percentage of Car and Truck Drivers Driving a Particular Type of Vehicle.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
What kind of vehicle are you driving?	Automobile/ Van	25	69.44%	0	0.00%	19	63.33%	0	0.00%
	SUV	6	16.67%	0	0.00%	9	30.00%	0	0.00%
	Pick-up	5	13.89%	0	0.00%	2	6.67%	0	0.00%
	Large truck	0	0.00%	2	12.50%	0	0.00%	0	0.00%
	Tractor-trailer	0	0.00%	14	87.50%	0	0.00%	10	100.00%
	Other (describe)	0	0.00%	0	0.00%	0	0.00%	0	0.00%

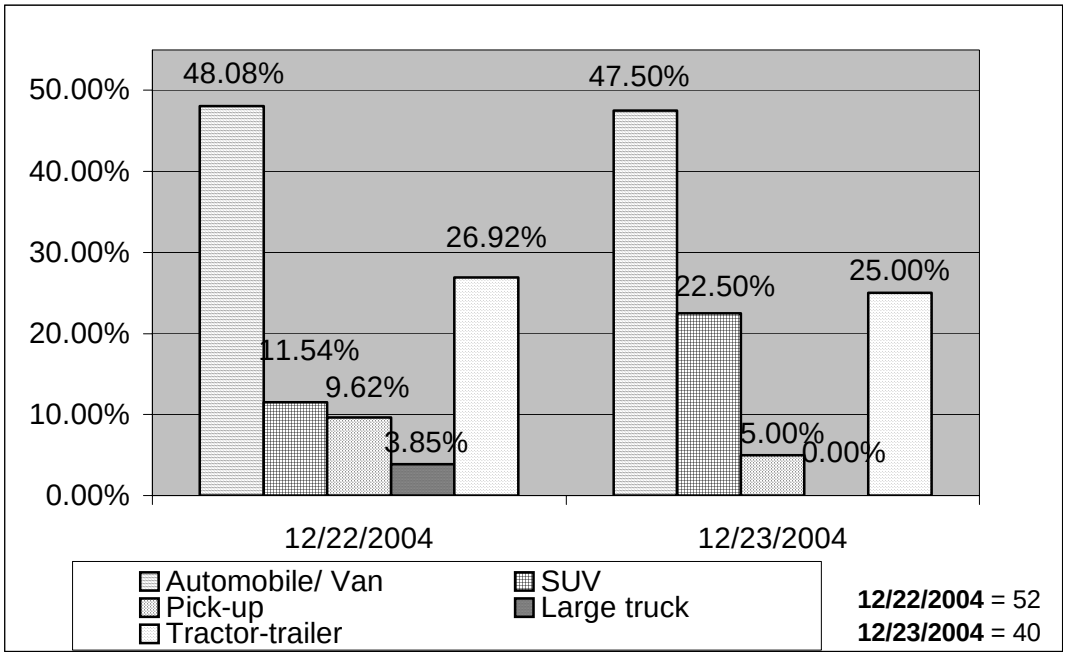

Figure 35: Percentage of Drivers Driving a Particular Type of Vehicle.

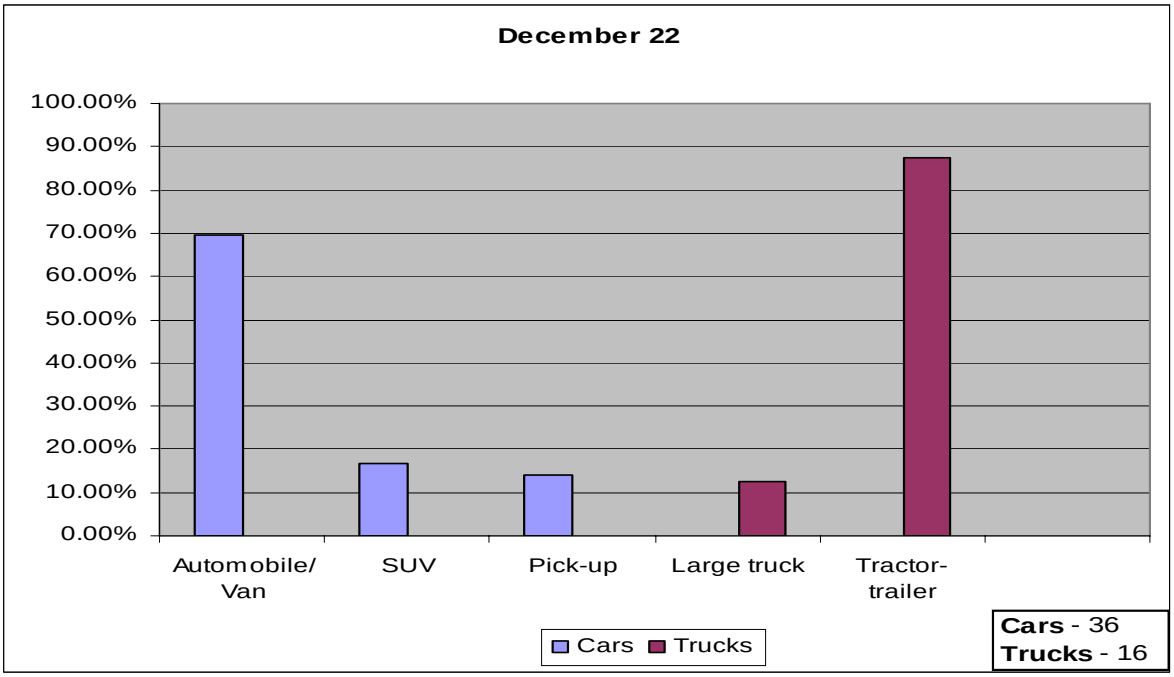

Figure 36: Percentage of Car and Truck Drivers Driving a Particular Type of Vehicle on December 22, 2004.

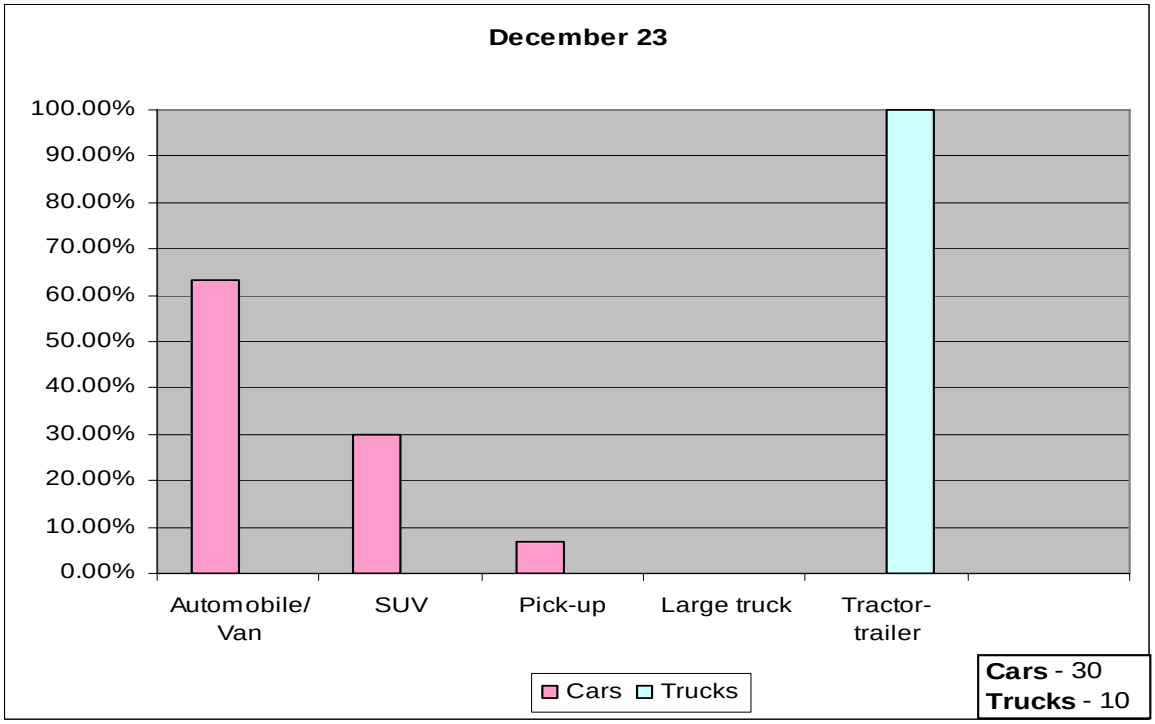

Figure 37: Percentage of Car and Truck Drivers Driving a Particular Type of Vehicle on December 23, 2004.

Question 6

Question 6 asked how many drivers were using two-wheel drive and how many were using four-wheel drive. On December 22 60% were using two-wheel drive while 19% were using four-wheel drive. On the 23rd 60% were using two-wheel drive while 22.5% were using four-wheel drive. Many drivers who were driving large trucks or tractor-trailers replied that they had neither two nor four-wheel drive, but were using the truck drive system available in the trucks. About 21% were using the truck drive system on the 22nd and 17.5% on the 23rd. Table 11 shows the responses and Figure 38 represents them graphically for both days.
On December 22, of all the car drivers, 75% said they were using two-wheel drive while 25% were using four-wheel drive. On the 23rd 70% were using two-wheel drives while 30% used four-wheel drive. Many drivers who were driving large trucks or tractor-trailers replied that they had neither two nor four-wheel drive, but were using the truck drive system available in the trucks. About 69% were using the truck drive system on the 22nd and 70% on the 23rd. Table 12 shows the responses and Figure 39 and Figure 40 represents them graphically for both days.

Table 11. Driver Responses for What Type of Drive System they were using.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
Did you drive using:	Two wheel drive (front/ rear)	31	59.62%	24	60.00%
	Four wheel drive	10	19.23%	9	22.50%
	Truck Drive System	11	21.15%	7	17.50%

Table 12. Car and Truck Driver Responses for What Type of Drive System they were using.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
Did you drive using :	Two wheel drive (front/ rear)	27	75.00%	4	25.00%	21	70.00%	3	30.00%
	Four wheel drive	9	25.00%	1	6.25%	9	30.00%	0	0.00%
	Truck Drive System	0	0.00%	11	68.75%	0	0.00%	7	70.00%

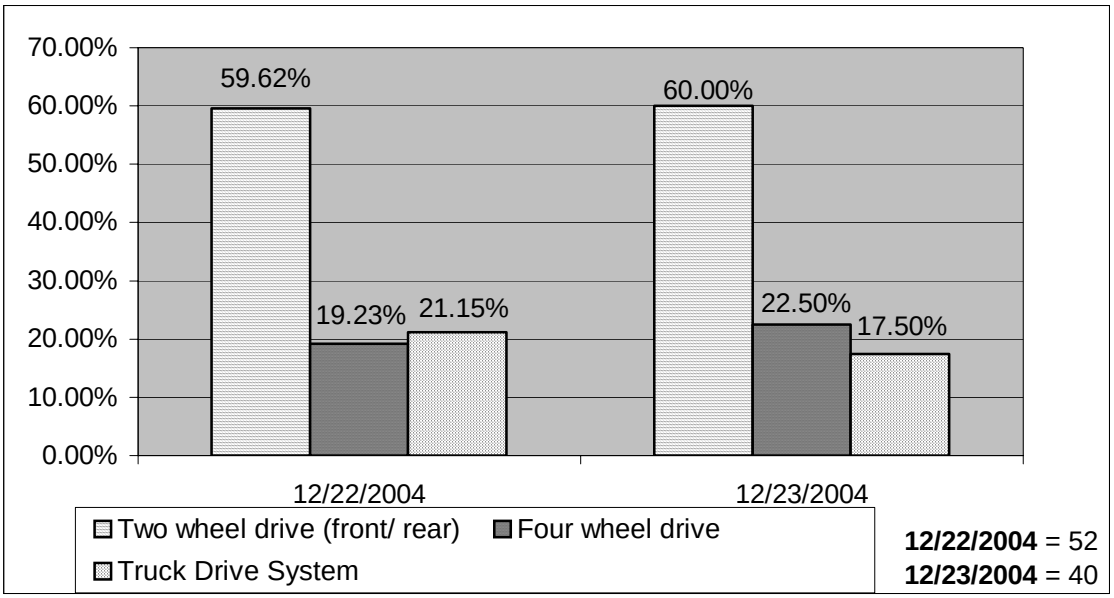

Figure 38: Graph Showing the Type of Drive System used in Percentages.

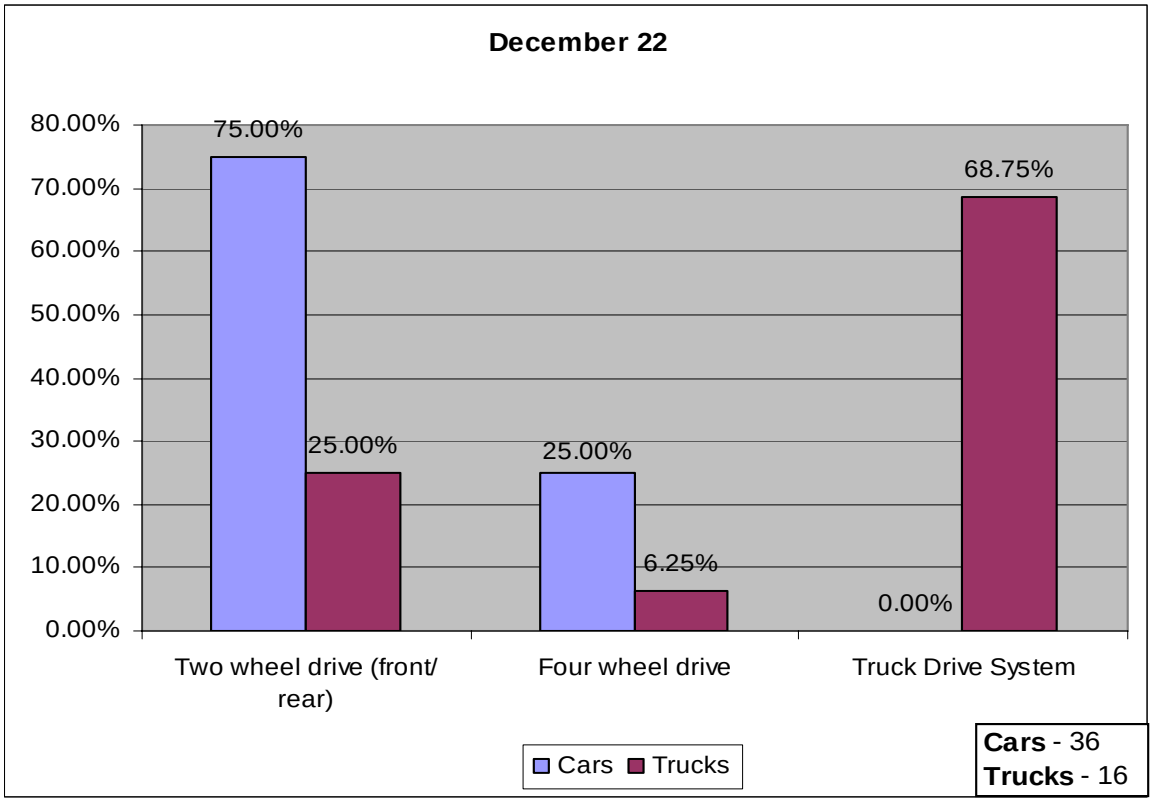

Figure 39: Graph showing the type of drive system used by car and truck drivers in percentages on December 22, 2004.

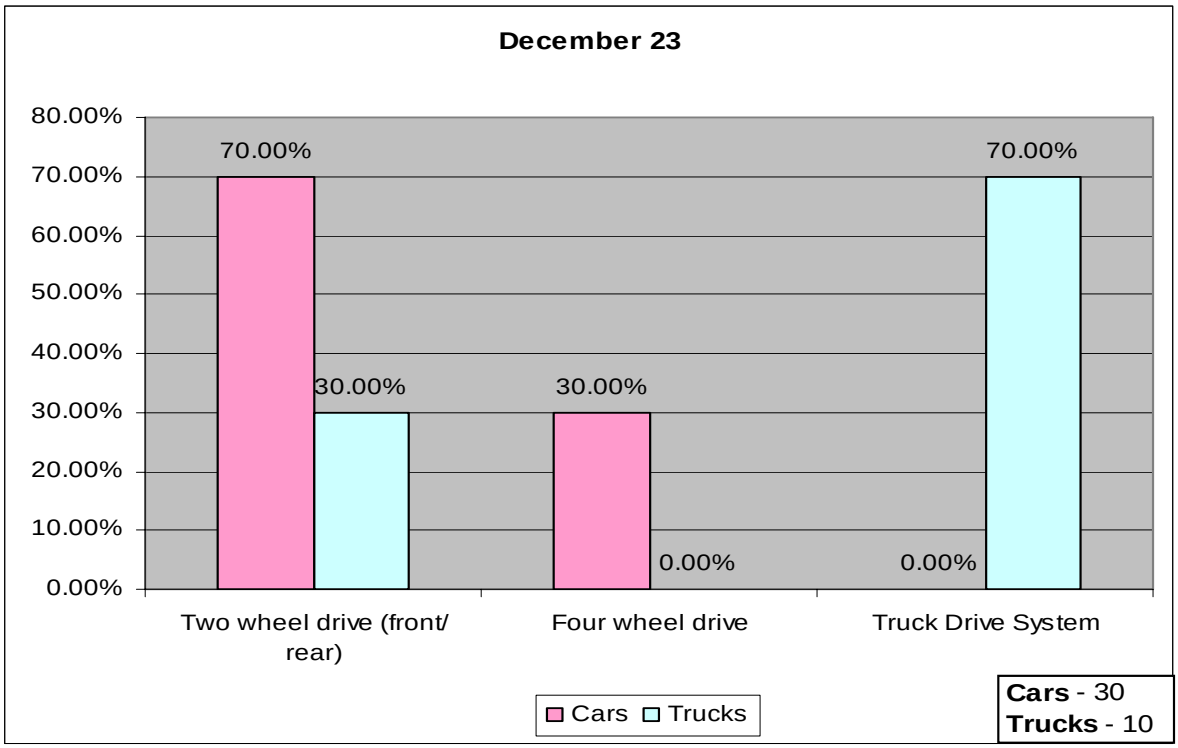

Figure 40: Graph Showing the Type of Drive System used by Car and Truck Drivers in Percentages on December 23, 2004.

Question 7

Question 7 asked how many drivers were using headlights while driving during the snowstorm. All except one truck driver (on December 23) who were surveyed were using their headlights, which can be observed in Table 13 for all respondents and Table 14 for car and truck drivers separately and in Figure 41, Figure 42 and Figure 43 graphically for December 22 and 23.

Table 13. Responses of Drivers using Headlights.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
Did you have your headlights on?	Yes	52	100.00%	39	97.50%
	No	0	0.00%	1	2.50%

Table 14. Responses of Car and Truck Drivers using Headlights.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
Did you have your headlights on?	Yes	36	100.00%	16	100.00%	30	100.00%	9	90.00%
	No	0	0.00%	0	0.00%	0	0.00%	1	10.00%

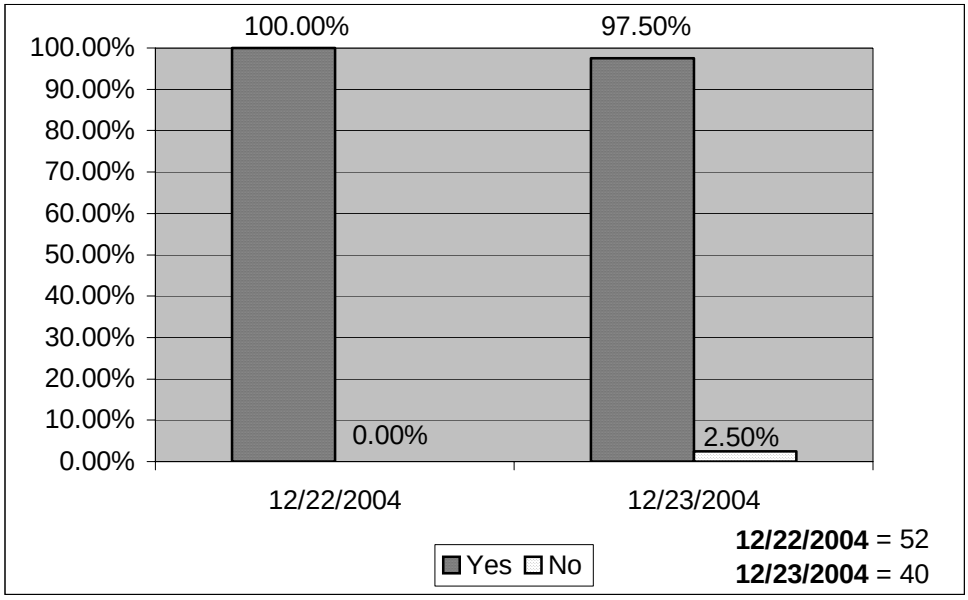

Figure 41: Graph Representing the Percentage of Drivers using Headlights.

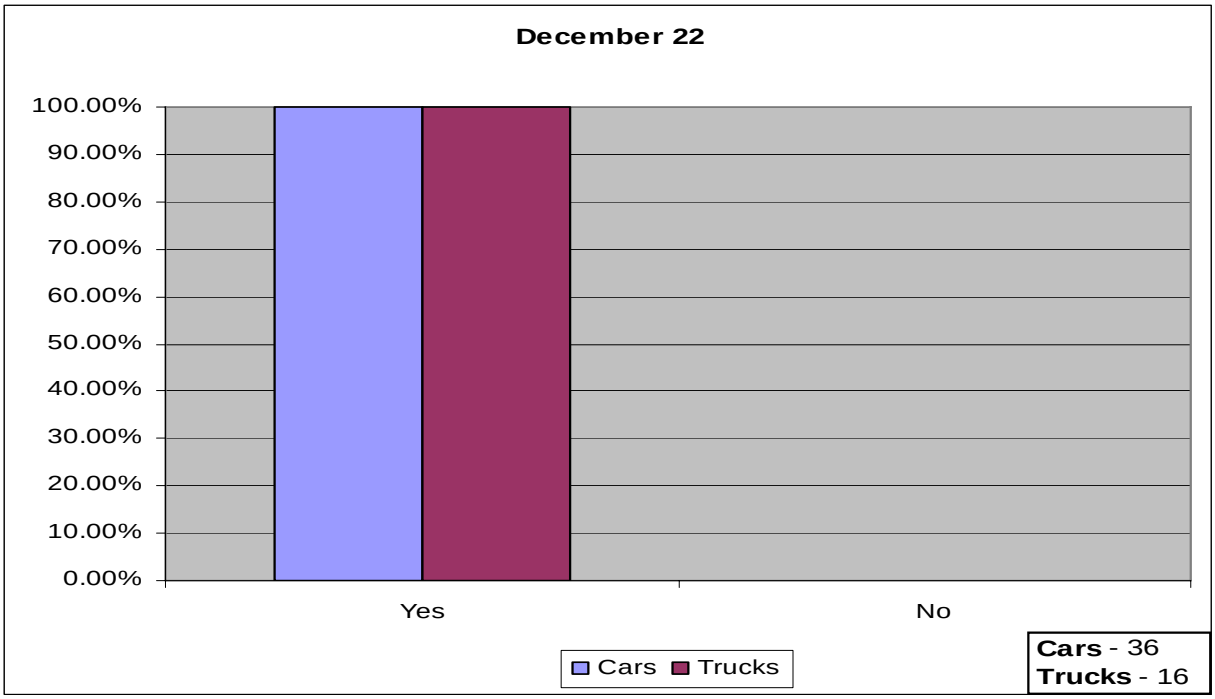

Figure 42: Graph Representing the Percentage of Car and Truck Drivers using Headlights on December 22, 2004.

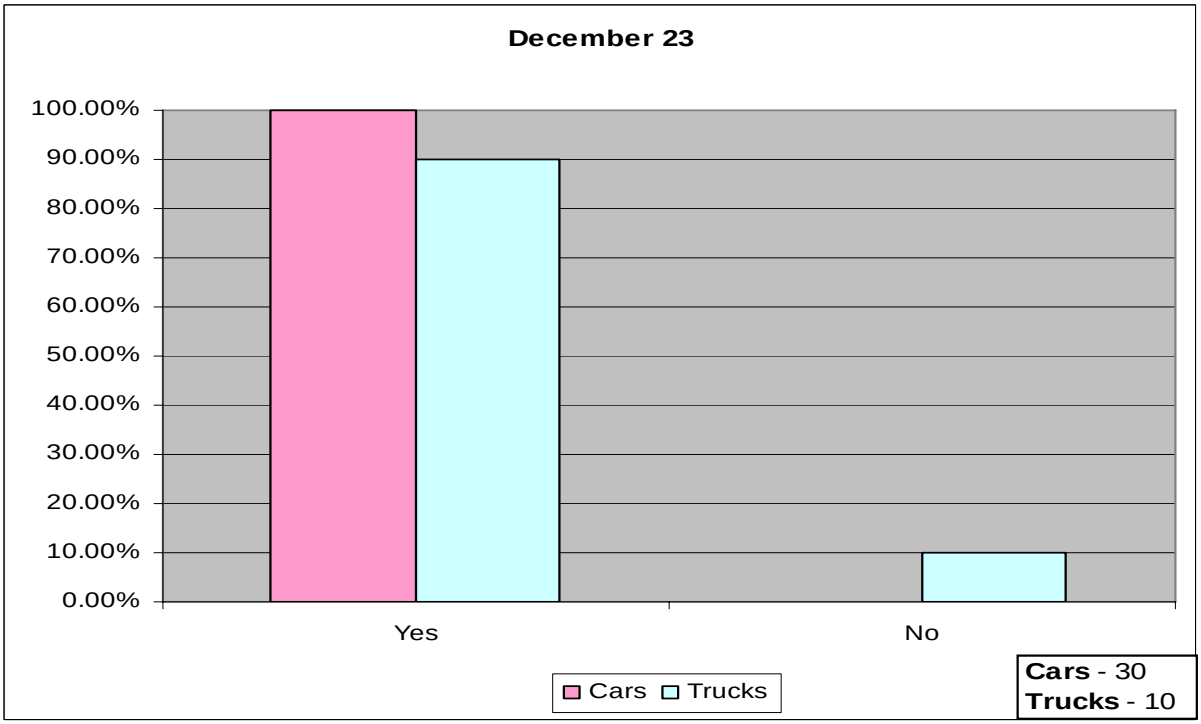

Figure 43: Graph Representing the Percentage of Car and Truck Drivers using Headlights on December 23, 2004.

Question 8

The drivers were asked in which lane they were driving for the last few miles on I-271 Southbound. More than half of them replied that they drove in the right lane. On the 22nd 77% and on the 23rd 70% answered that they were using the right lane for most part during the drive for the last few miles. A few drivers answered that they were not sure about which lane they were driving, generally because the lanes were covered with snow and they could not tell which lane they were in, and some were using both lanes during the last few miles. Table 15 shows the number of respondents using the right and left lane. Figure 44 shows the percentages of drivers using right and left lanes.
On the 22nd 69% of the car drivers and 94% of truck drivers and on the 23rd 73% of car drivers and 60% of truck drivers answered that they were using the right lane for most part during the drive for the last few miles. A few drivers answered that they were not sure about which lane they were driving, generally because the lanes were covered with snow and they could not tell which lane they were in, and some were using both lanes during the last few miles. Table 16 shows the number of respondents using the right and left lane. Figure 45 and Figure 46 shows the percentages of drivers using right and left lanes on 22nd and 23rd December respectively.

Table 15. Responses of Drivers about the Lane they were Driving for the last few Miles.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
In which lane did you travel on this freeway for the last few miles or so?	Mostly in the right lane	40	76.92%	28	70.00%
	Mostly in the left or passing lane	11	21.15%	10	25.00%
	Both/ Not sure	1	1.92%	2	5.00%

Table 16. Responses of Car and Truck Drivers about the Lane they were Driving for the last few Miles.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
In which lane did you travel on this freeway for the last few miles or so?	Mostly in the right lane	25	69.44%	15	93.75%	22	73.33%	6	60.00%
	Mostly in the left or passing lane	11	30.56%	0	0.00%	8	26.67%	2	20.00%
	Both/ Not sure	0	0.00%	1	6.25%	0	0.00%	2	20.00%

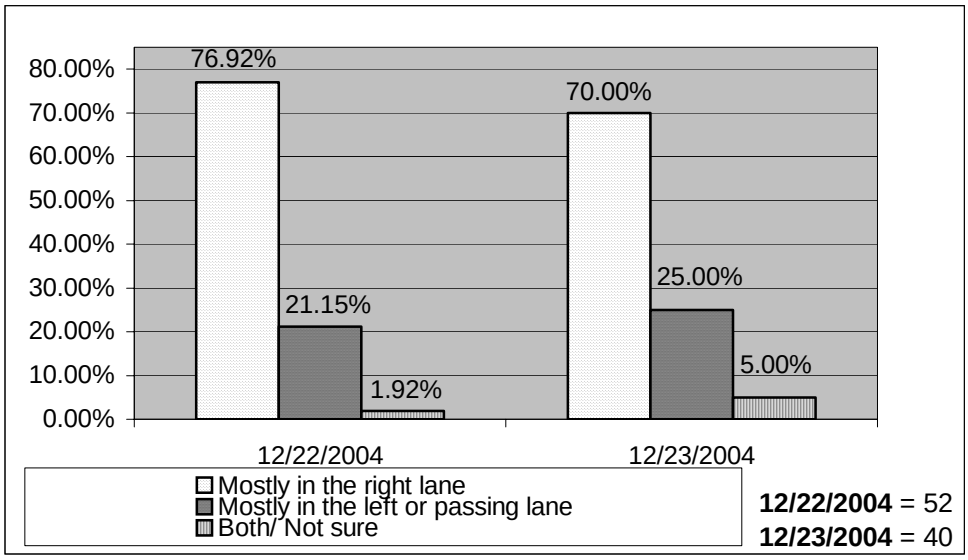

Figure 44: Graphical Representation of the Percentage of Drivers Driving in all Lanes.

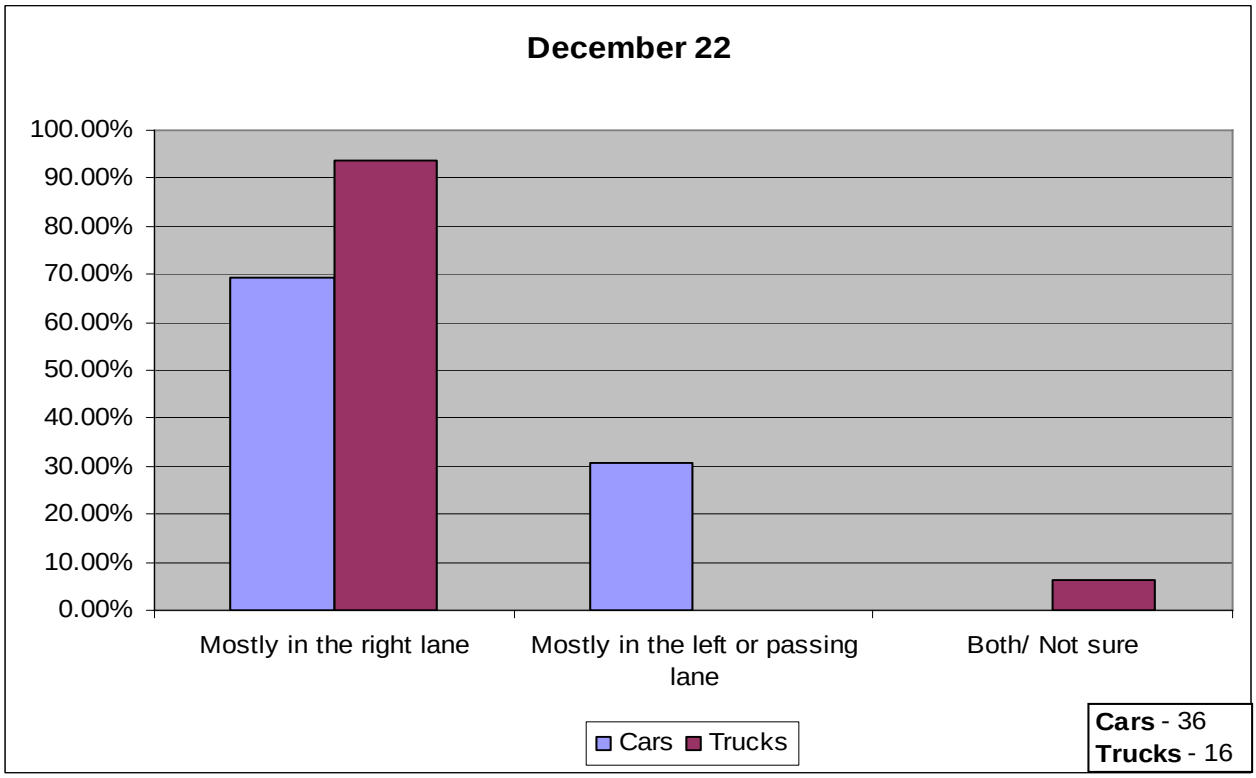

Figure 45: Graphical Representation of the Percentage of Car and Truck Drivers driving in all Lanes on December 22, 2004.

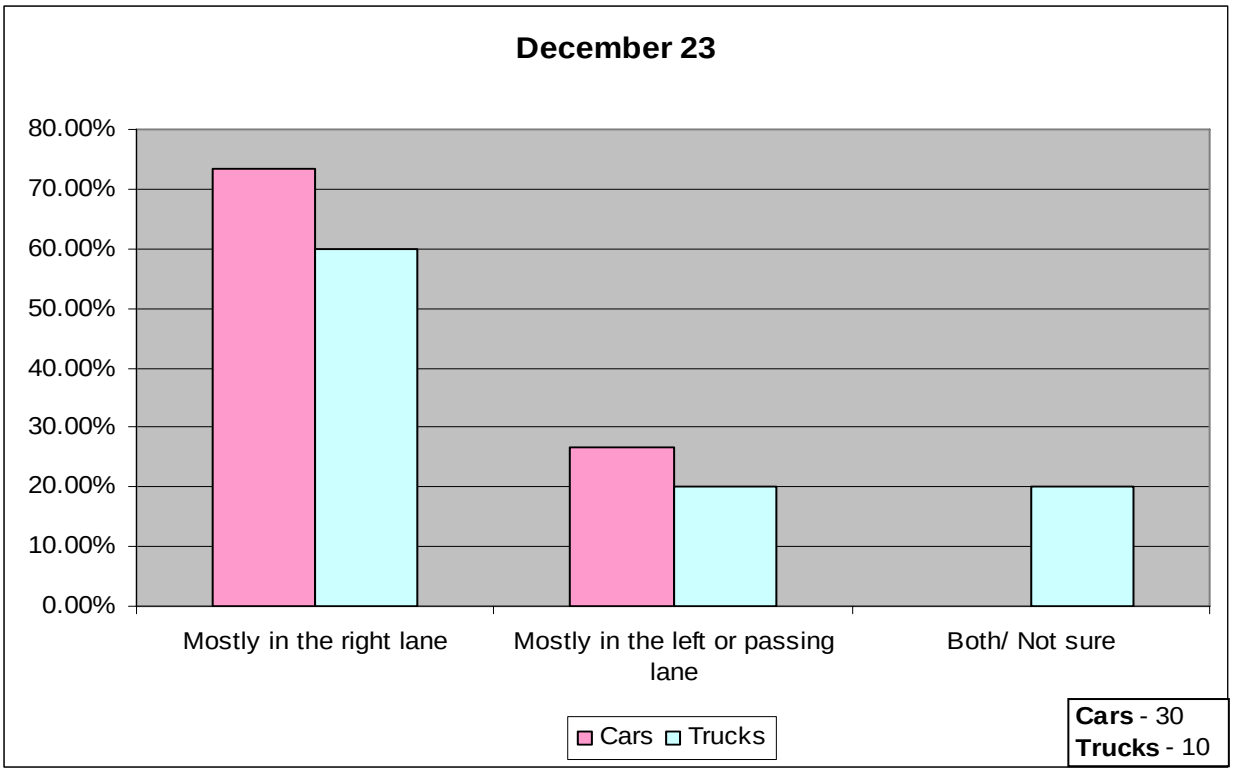

Figure 46: Graphical Representation of the Percentage of Car and Truck Drivers driving in all Lanes on December 23, 2004.

Question 9

Question 9 asked about the speed at which the drivers were driving on I-271 Southbound during the snowstorm. The speed limit on that stretch of the road is 65 mph. The plurality of drivers answered that they were going more than 20 mph below the usual speed limit. Table 17 shows the responses for all drivers. Figure 47 shows the percentages for all drivers. Table 18 shows the responses of car and truck drivers separately. Figure 48 and Figure 49 show the percentages graphically for December 22 and 23 for car and truck drivers separately. The drivers that were driving about the speed limit replied that they considered themselves experienced at driving in snowstorms.

Table 17. Responses about the Driver's Speed on I-271 Southbound.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
At what speed did you drive most of the time during the last few miles or so?	About the speed limit	8	15.38%	4	10.00%
	Slightly below the speed limit (5-10 mph below	6	11.54%	6	15.00%
	Considerably below the speed limit (10-20 mph below)	13	25.00%	15	37.50%
	Very slowly (more than 20 mph below the speed limit)	25	48.08%	15	37.50%

Table 18. Responses about the Car and Truck Driver's Speed on I-271 Southbound.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
At what speed did you drive most of the time during the last few miles or so?	About the speed limit	3	8.33%	5	31.25%	3	10.00%	1	10.00%
	Slightly below the speed limit (5-10 mph below	4	11.11%	2	12.50%	5	16.67%	1	10.00%
	Considerably below the speed limit (10-20 mph below)	10	27.78%	3	18.75%	11	36.67%	4	40.00%
	Very slowly (more than 20 mph below the speed limit)	19	52.78%	6	37.50%	11	36.67%	4	40.00%

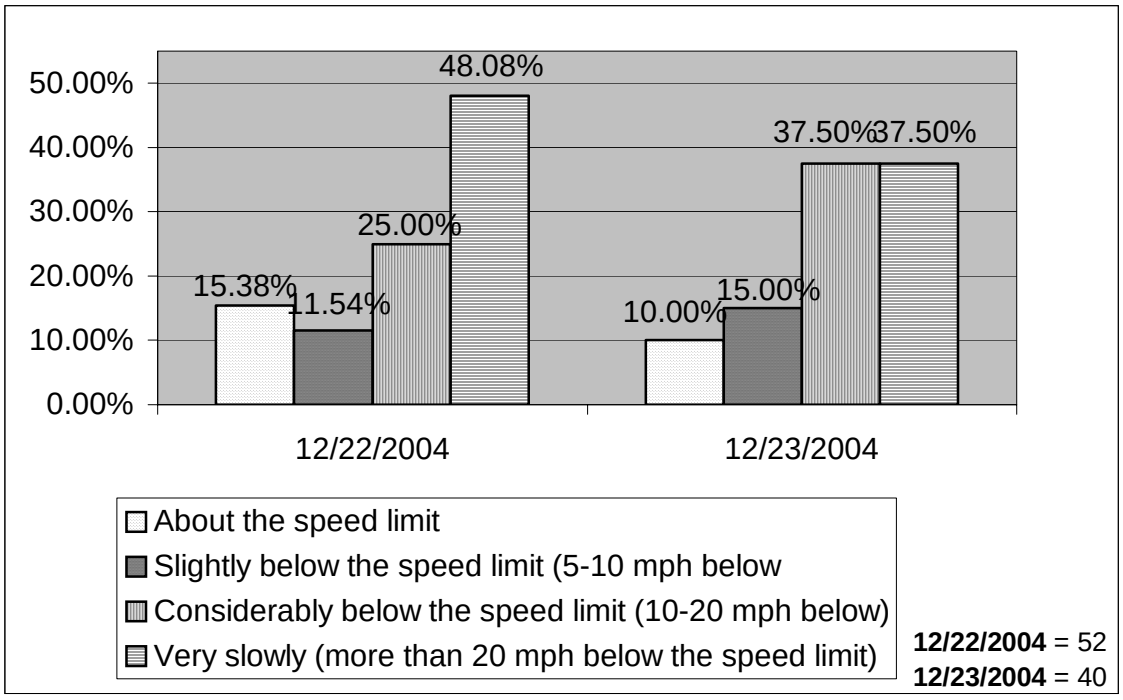

Figure 47: Graphical Representation of Driver Speeds.

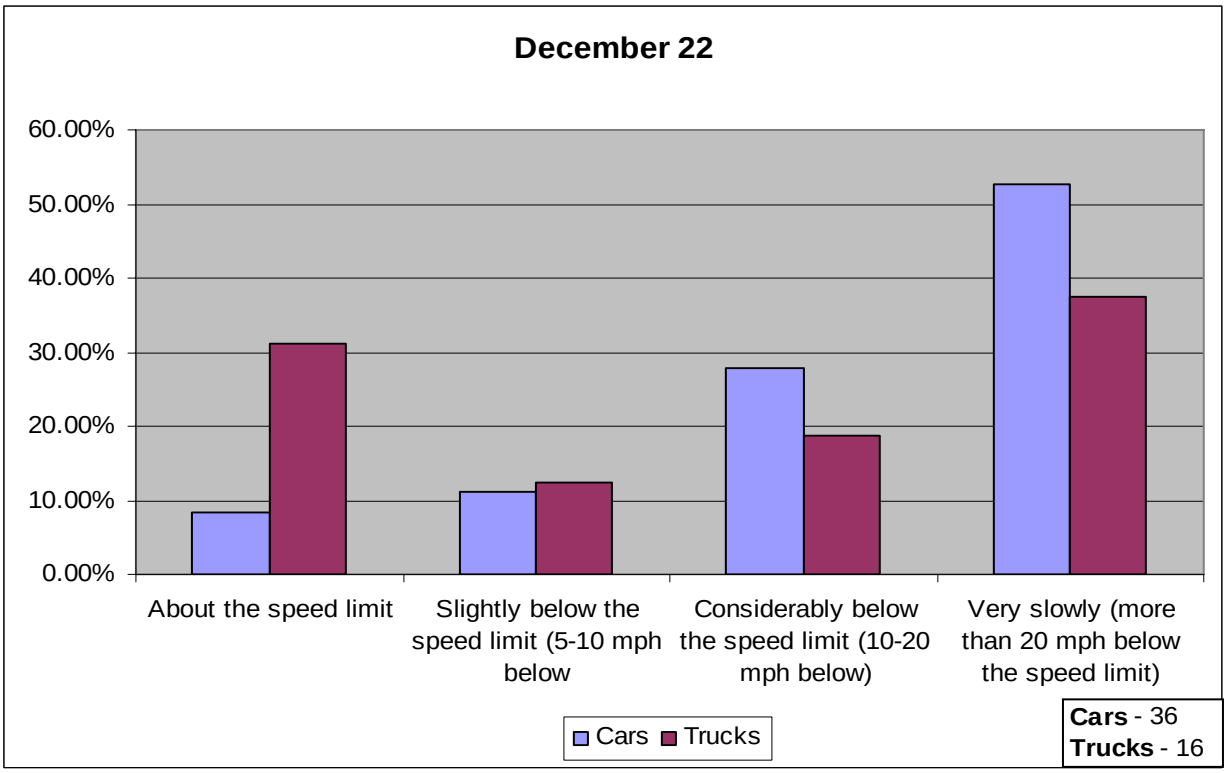

Figure 48: Graphical Representation of Car and Truck Driver Speeds on December 22, 2004.

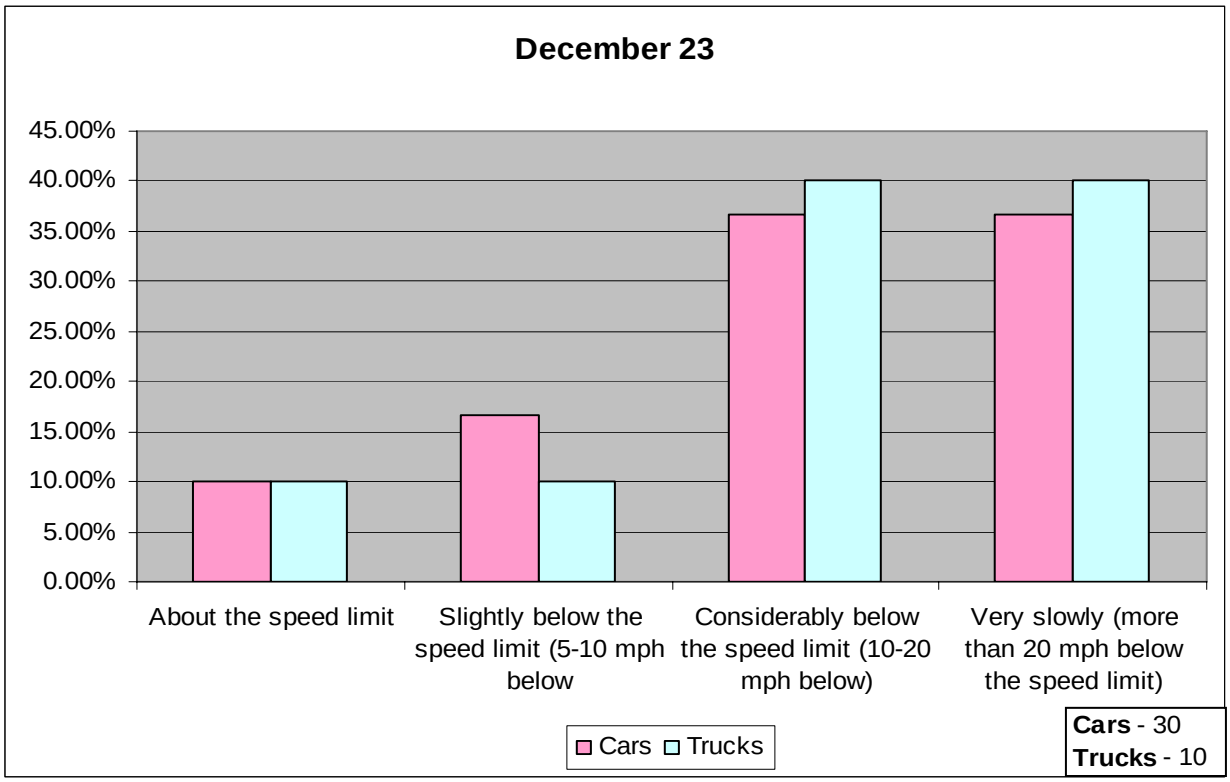

Figure 49: Graphical Representation of Car and Truck Driver Speeds on December 23, 2004.

Question 10

Following upon the previous question, the drivers were asked to rank the factors which they thought that reduced their driving speed. It is worth mentioning here that some of the drivers instead of ranking the factors checked all the factors that they thought affected their driving speed. In such cases equal weighting was given to all the factors. However, their response was different for both days. Most of them considered that the road surface condition mainly due to snow on road was the main factor that reduced their driving speed on December 22. But on December 23, most drivers thought that the road surface condition mainly due to ice and slippery road surface was the main factor in reducing their speed. Table 19 represents the total responses of drivers. Table 20 and Table 21 show the ranking of the factors by the drivers on December 22 and December 23 respectively.
Table 22 represents the total responses of car and truck drivers for both the days. Table 40 and Table 24 show the ranking of the factors for the car and truck drivers on December 22, while Table 25 and Table 26 show the ranking of factors for car and truck drivers on December 23.

Table 19. Responses on Why the Drivers Reduced their Driving Speed.

Date		12/22/2004	12/23/2004
		# Respondents	# Respondents
What are the factors that reduced the driving speed?	The traffic around you (in front, in back)	27	18
	The visibility conditions due to falling snow, freezing rain, or other precipitation	34	12
	The visibility conditions due to blowing snow	9	3
	The visibility conditions due to fog	4	2
	The road surface conditions, mainly snow on road	41	26
	The road surface conditions, mainly icy and slippery road surface	20	29
	Activity near road such as construction or law enforcement	5	1
	Other (specify)	0	0
	None; driving was fine	0	0

Table 20. Ranking of Factors that Reduced Driving Speed on December 22nd, 2004 (Car and Truck Drivers together).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	11	7	7	1	1	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	13	15	5	1	0	0	0	0	0
The visibility conditions due to blowing snow	5	2	0	1	0	1	0	0	0
The visibility conditions due to fog	1	1	0	0	0	0	2	0	0
The road surface conditions, mainly snow on road	30	5	5	1	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	9	8	1	2	0	0	0	0	0
Activity near road such as construction or law enforcement	0	2	0	0	2	1	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 21. Ranking of Factors that Reduced Driving Speed on December 23rd, 2004 (Car and Truck Drivers together).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	5	5	7	0	1	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	5	3	4	0	0	0	0	0	0
The visibility conditions due to blowing snow	0	2	0	1	0	0	0	0	0
The visibility conditions due to fog	0	0	2	0	0	0	0	0	0
The road surface conditions, mainly snow on road	13	11	2	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	18	9	2	0	0	0	0	0	0
Activity near road such as construction or law enforcement	1	0	0	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 22. Responses on Why the Car and Truck Drivers Reduced their Driving Speed.

Dates		12/22/2004		12/23/2004	
Vehicle Type		Cars	Trucks	Cars	Trucks
		#	#	#	#
What are the factors that reduced the driving speed?	The traffic around you (in front, in back)	19	8	13	5
	The visibility conditions due to falling snow, freezing rain, or other precipitation	26	8	10	2
	The visibility conditions due to blowing snow	6	3	2	1
	The visibility conditions due to fog	2	2	1	1
	The road surface conditions, mainly snow on road	29	12	20	6
	The road surface conditions, mainly icy and slippery road surface	13	7	21	8
	Activity near road such as construction or law enforcement	3	2	0	1
	Other (specify)	0	0	0	0
	None; driving was fine	0	0	0	0

Table 23. Ranking of Factors that Reduced Driving Speed of Car Drivers on December 22, 2004.

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	5	7	5	1	1	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	8	12	5	1	0	0	0	0	0
The visibility conditions due to blowing snow	3	2	0	1	0	0	0	0	0
The visibility conditions due to fog	0	1	0	0	0	0	1	0	0
The road surface conditions, mainly snow on road	21	4	3	1	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	6	5	1	1	0	0	0	0	0
Activity near road such as construction or law enforcement	0	1	0	0	1	1	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 24. Ranking of Factors that Reduced Driving Speed of Truck Drivers on December 22, 2004.

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	6	0	2	0	0	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	5	3	0	0	0	0	0	0	0
The visibility conditions due to blowing snow	2	0	0	0	0	1	0	0	0
The visibility conditions due to fog	1	0	0	0	0	0	1	0	0
The road surface conditions, mainly snow on road	9	1	2	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	3	3	0	1	0	0	0	0	0
Activity near road such as construction or law enforcement	0	1	0	0	1	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 25. Ranking of Factors that Reduced Driving Speed of Car Drivers on December 23, 2004.

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	2	5	5	0	1	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	5	2	3	0	0	0	0	0	0
The visibility conditions due to blowing snow	0	1	0	1	0	0	0	0	0
The visibility conditions due to fog	0	0	1	0	0	0	0	0	0
The road surface conditions, mainly snow on road	12	6	2	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	13	7	1	0	0	0	0	0	0
Activity near road such as construction or law enforcement	0	0	0	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 26. Ranking of Factors that Reduced Driving Speed of Truck Drivers on December 23, 2004.

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	3	0	2	0	0	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	0	1	1	0	0	0	0	0	0
The visibility conditions due to blowing snow	0	1	0	0	0	0	0	0	0
The visibility conditions due to fog	0	0	1	0	0	0	0	0	0
The road surface conditions, mainly snow on road	1	5	0	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	5	2	1	0	0	0	0	0	0
Activity near road such as construction or law enforcement	1	0	0	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Question 11

The drivers were asked about the road surface condition for the last few miles in which they were driving. Almost 85% of the drivers on both days opined that the road surface was 60% or less clear from edgeline to edgeline. Table 27 and Figure 50 show these results for car and truck drivers together and Table 28. Figure 51 and Figure 52 show these results separated for car and truck drivers.

Table 27. Number of Responses and Percentages on the Road Condition.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
How was the road surface condition for the last few miles or so?	100 % clear pavement from edgeline to edgeline	0	0.00%	0	0.00%
	90 % clear pavement from edgeline to edgeline	2	3.85%	0	0.00%
	80 % clear pavement from edgeline to edgeline	3	5.77%	1	2.50%
	70 % clear pavement from edgeline to edgeline	2	3.85%	5	12.50%
	60 % or less clear pavement from edgeline to edgeline	45	86.54%	34	85.00%

Table 28. Number of Responses and Percentages on the Road Condition (car and truck drivers separate).

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How was the road surface condition for the last few miles or so?	100 % clear pavement from edgeline to edgeline	0	0.00%	0	0.00%	0	0.00%	0	0.00%
	90 % clear pavement from edgeline to edgeline	1	2.78%	1	6.25%	0	0.00%	0	0.00%
	80 % clear pavement from edgeline to edgeline	1	2.78%	2	12.50%	1	3.33%	0	0.00%
	70 % clear pavement from edgeline to edgeline	1	2.78%	1	6.25%	4	13.33%	1	10.00%
	60 % or less clear pavement from edgeline to edgeline	33	91.67%	12	75.00%	25	83.33%	9	90.00%

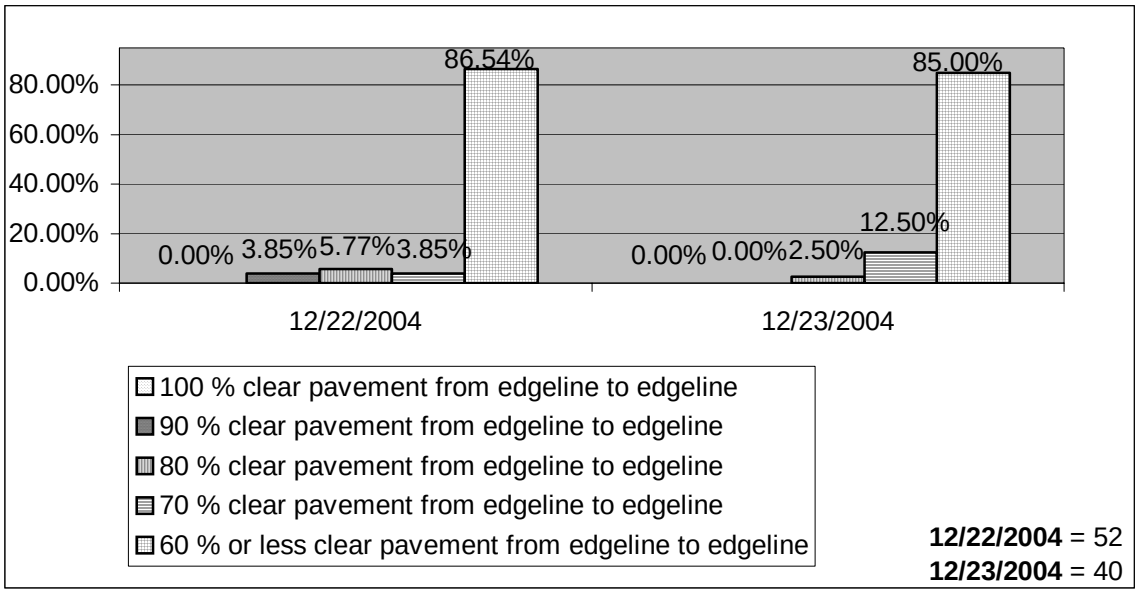

Figure 50: Response Percentage for each Factor about the Road Condition.

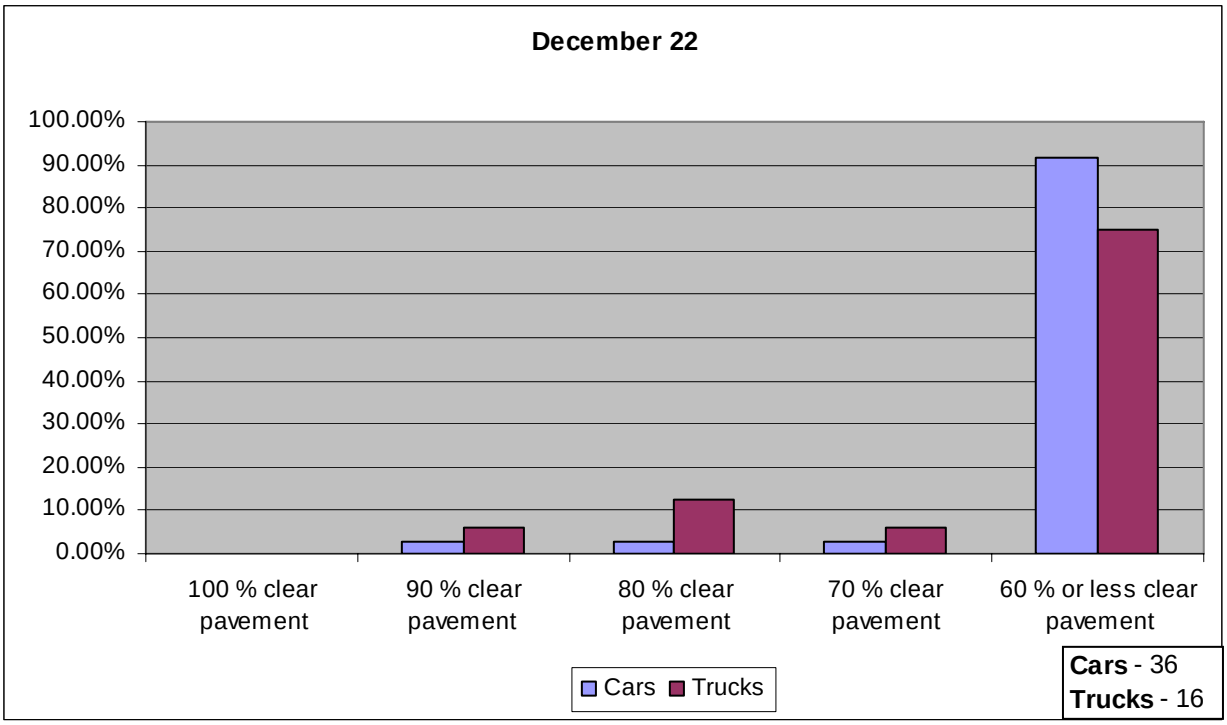

Figure 51: Response Percentage for each Factor about the Road Condition on December 22, 2004 (car and truck drivers separate).

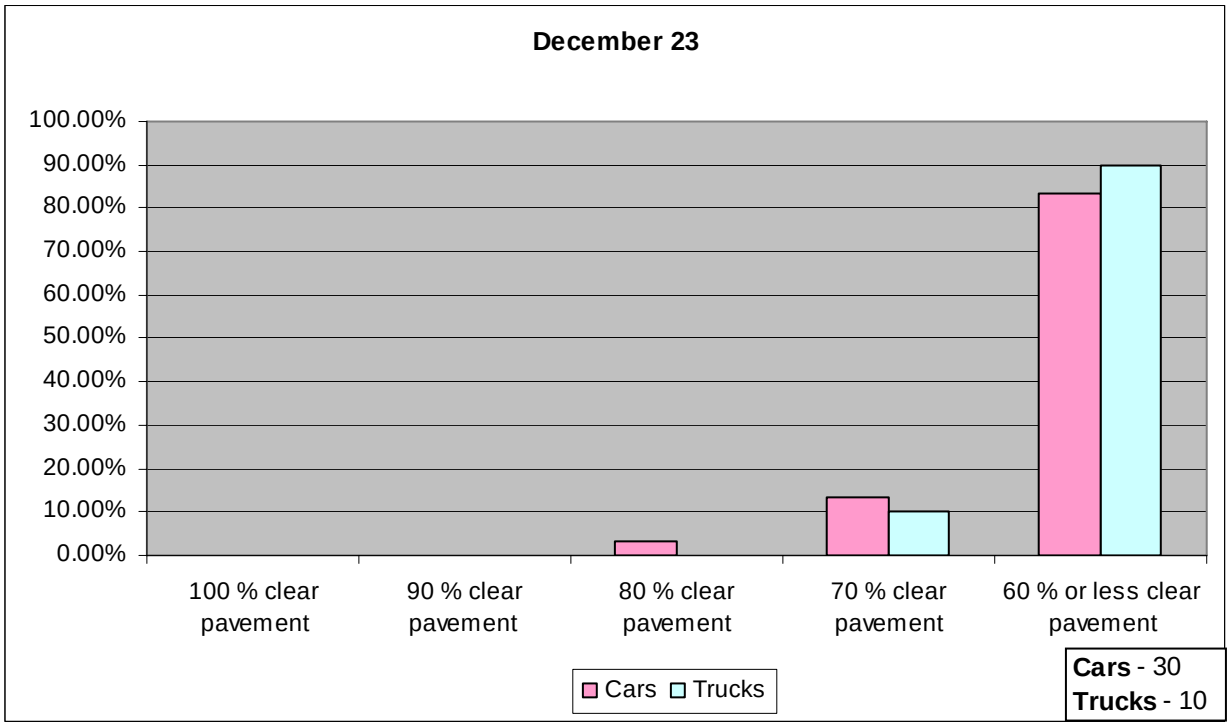

Figure 52: Response Percentage for each Factor about the Road Condition on December 23, 2004 (car and truck drivers separate).

Question 12

Question 12 asked about the conditions in the lane they drove for most part during the last few miles. Respondents checked all the options which they thought that prevailed in the lane they drove. On December 22, many people answered that their lane was covered with snow, while on the 23rd, almost equal percentage of drivers replied that their lane was covered with snow, ice, and slush. Table 29 shows the driver responses and Table 30 shows car and truck driver responses separately.

Table 29. Driver Responses about the Conditions in the Lane they Drove.

Date		12/22/2004	12/23/2004
		# Respondents	# Respondents
Describe the current conditions in the lane you drove in the most for the last few miles or so.	Clear	0	0
	Snow covered	40	16
	Snow covered in spots	5	6
	Drifted snow	0	1
	Icy	4	12
	Icy in spots	6	7
	Slush covered	11	12
	Blocked	0	2

Table 30. Car and Truck Driver Responses about the Conditions in the Lane they Drove.

Dates		12/22/2004		12/23/2004	
Vehicle Type		Cars	Trucks	Cars	Trucks
		#	#	#	#
Describe the current conditions in the lane you drove in the most for the last few miles or so.	Clear	0	0	0	0
	Snow covered	27	13	10	6
	Snow covered in spots	3	2	6	0
	Drifted snow	0	0	1	0
	Icy	2	2	10	2
	Icy in spots	4	2	6	1
	Slush covered	9	2	10	2
	Blocked	0	0	2	0

Question 13

The drivers were asked if there were wheel tracks on which they could drive, if the roads were covered with snow. About 50% on the 22nd answered that there were wheel tracks on both lanes, while on the 23rd 47.5% answered the same. About 38.5% replied on the 22nd that there were tracks only on right or driving lane while on the 23rd, 40% replied the same. Table 31 shows the responses and they can be seen graphically Figure 53.
About 50% of the car drivers on the 22nd and 23rd answered that there were wheel tracks in the right lane, while 81% of truck drivers on 22nd and 70% of them answered that there were wheel tracks on both lanes. About 36% of car drivers replied on the 22nd that there were tracks on both the lanes while on the 23rd, 40% of them replied the same. Table 32 shows the responses and they can be seen graphically in Figure 54 and Figure 55.

Table 31. Responses on Visibility of Wheel Tracks.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
If the road had snow cover, were there wheel tracks you could drive on?	No tracks - the road was covered with snow	5	9.62%	5	12.50%
	Wheel tracks in the right (driving) lane only	20	38.46%	16	40.00%
	Wheel tracks in the left (passing) lane only	1	1.92%	0	0.00%
	Wheel tracks in both lanes	26	50.00%	19	47.50%

Table 32. Car and Truck Driver Responses on Visibility of Wheel Tracks.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
If the road had snow cover, were there wheel tracks you could drive on?	No tracks - the road was covered with snow	4	11.11%	1	6.25%	4	13.33%	1	10.00%
	Wheel tracks in the right (driving) lane only	18	50.00%	2	12.50%	14	46.67%	2	20.00%
	Wheel tracks in the left (passing) lane only	1	2.78%	0	0.00%	0	0.00%	0	0.00%
	Wheel tracks in both lanes	13	36.11%	13	81.25%	12	40.00%	7	70.00%

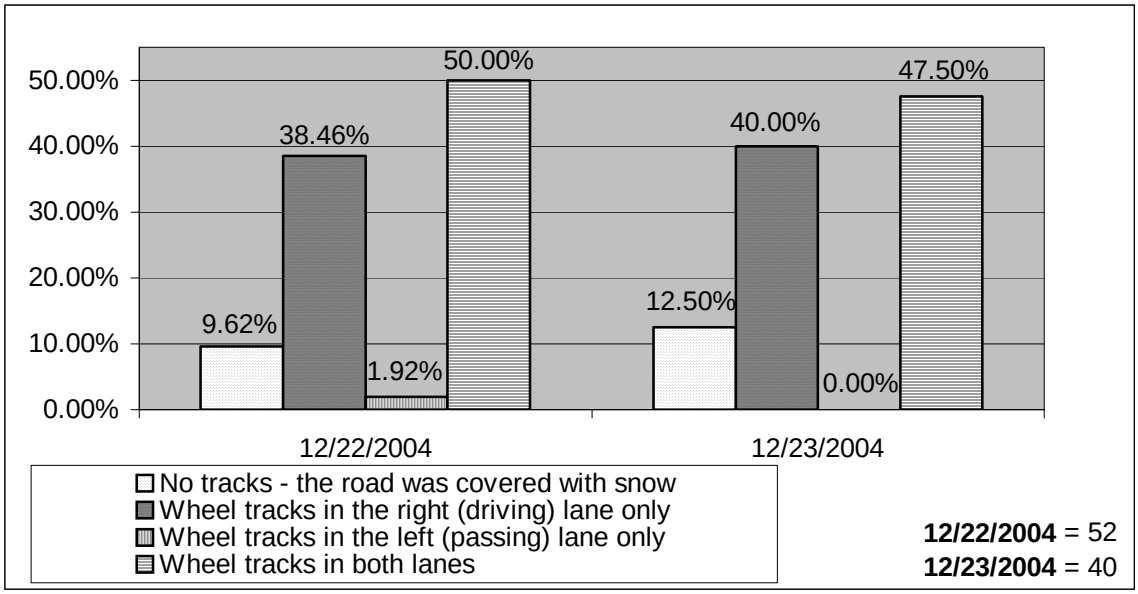

Figure 53: Percentage of Wheel Tracks Visibility on the Lanes.

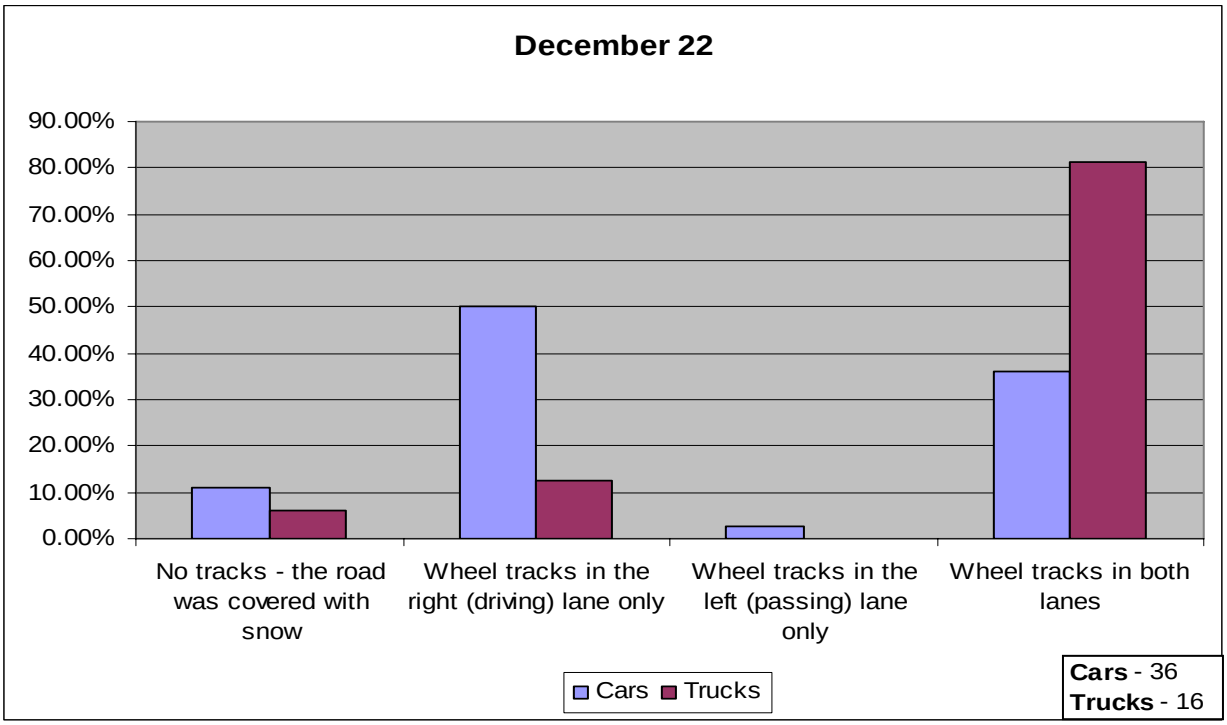

Figure 54: Percentage car and truck drivers responses of wheel tracks visibility on the lanes on December 22, 2004.

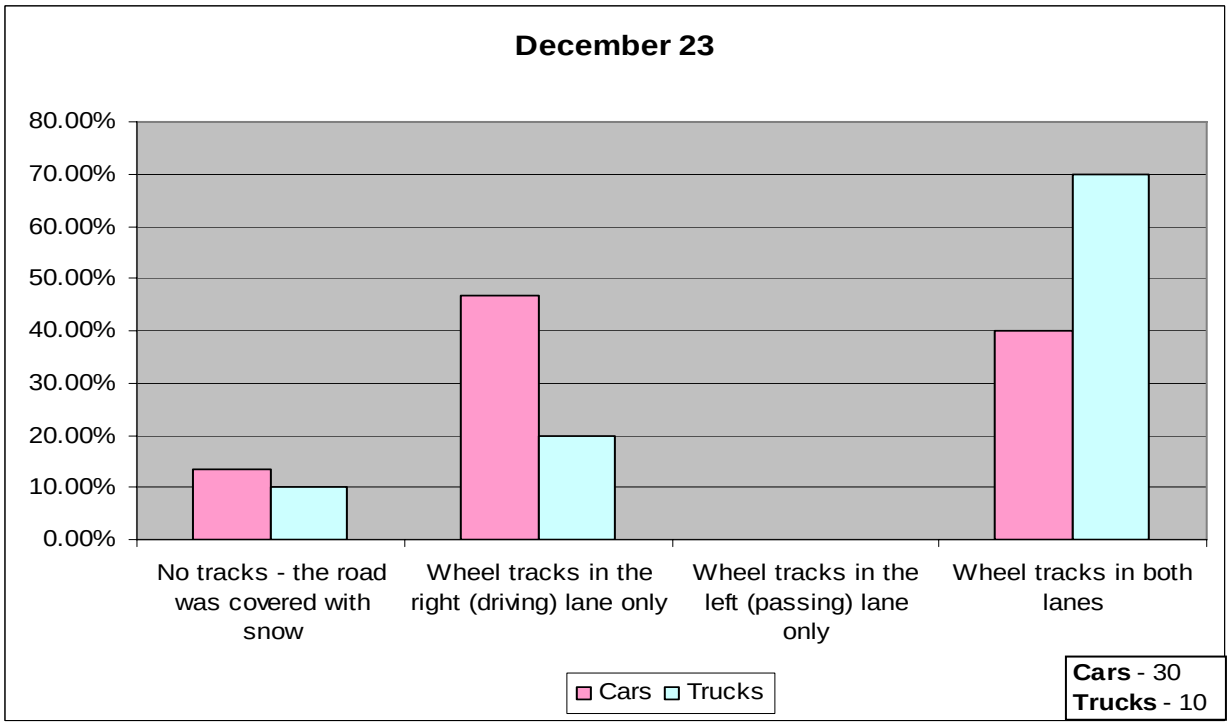

Figure 55: Percentage Car and Truck Drivers Responses of Wheel Tracks Visibility on the Lanes on December 23, 2004.

Question 14

Drivers were asked to rate the clearing and treatment of the roads for the last few miles. Table 33 shows all of the responses and in Figure 56 they can be seen graphically. Table 34 shows the responses separated for car and truck drivers and in Figure 57 and Figure 58 they can be seen graphically for both the days. Respondents tended to rate the road treatment as fair or poor. A few responded that the treatment was very good or excellent considering the extreme conditions of the storm, while others said that the treatment in nearby states (Pennsylvania and New York) was better.

Table 33. Responses on Road Clearing and Treatment.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
How would you rate the clearing and treatment of the last few miles or so of this road during this storm?	Excellent	0	0.00%	2	5.00%
	Very Good	6	11.54%	3	7.50%
	Good	10	19.23%	9	22.50%
	Fair	12	23.08%	15	37.50%
	Poor	24	46.15%	11	27.50%

Table 34. Responses of Car and Truck Drivers on Road Clearing and Treatment.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How would you rate the clearing and treatment of the last few miles or so of this road during this storm?	Excellent	0	0.00%	0	0.00%	1	3.33%	1	10.00%
	Very Good	3	8.33%	3	18.75%	3	10.00%	0	0.00%
	Good	8	22.22%	2	12.50%	7	23.33%	2	20.00%
	Fair	8	22.22%	4	25.00%	13	43.33%	2	20.00%
	Poor	17	47.22%	7	43.75%	6	20.00%	5	50.00%

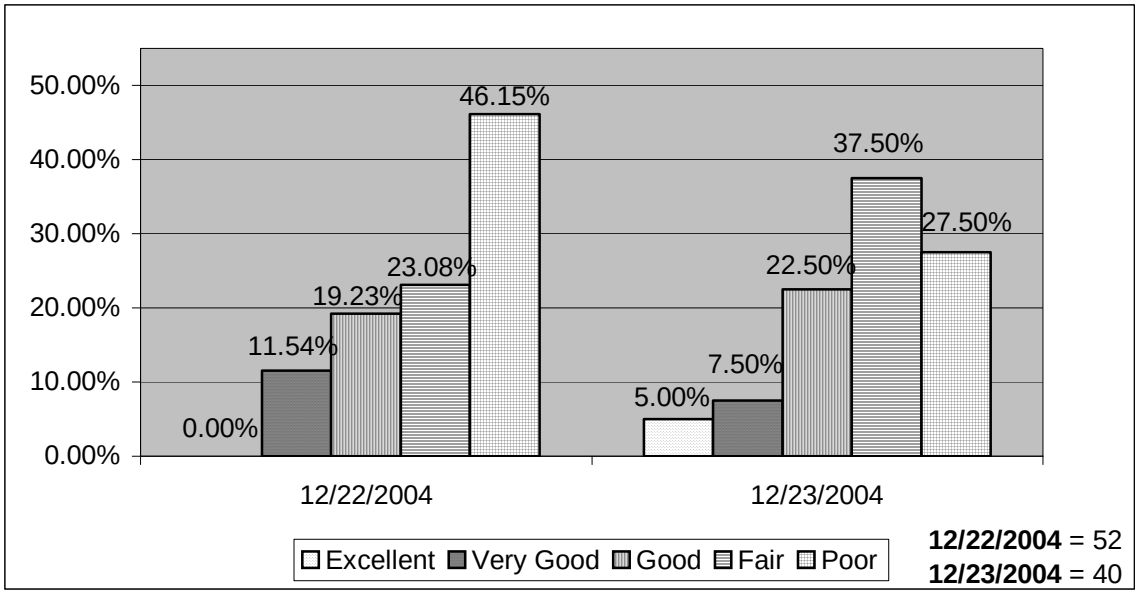

Figure 56: Rating of the Road Clearing and Treatment.

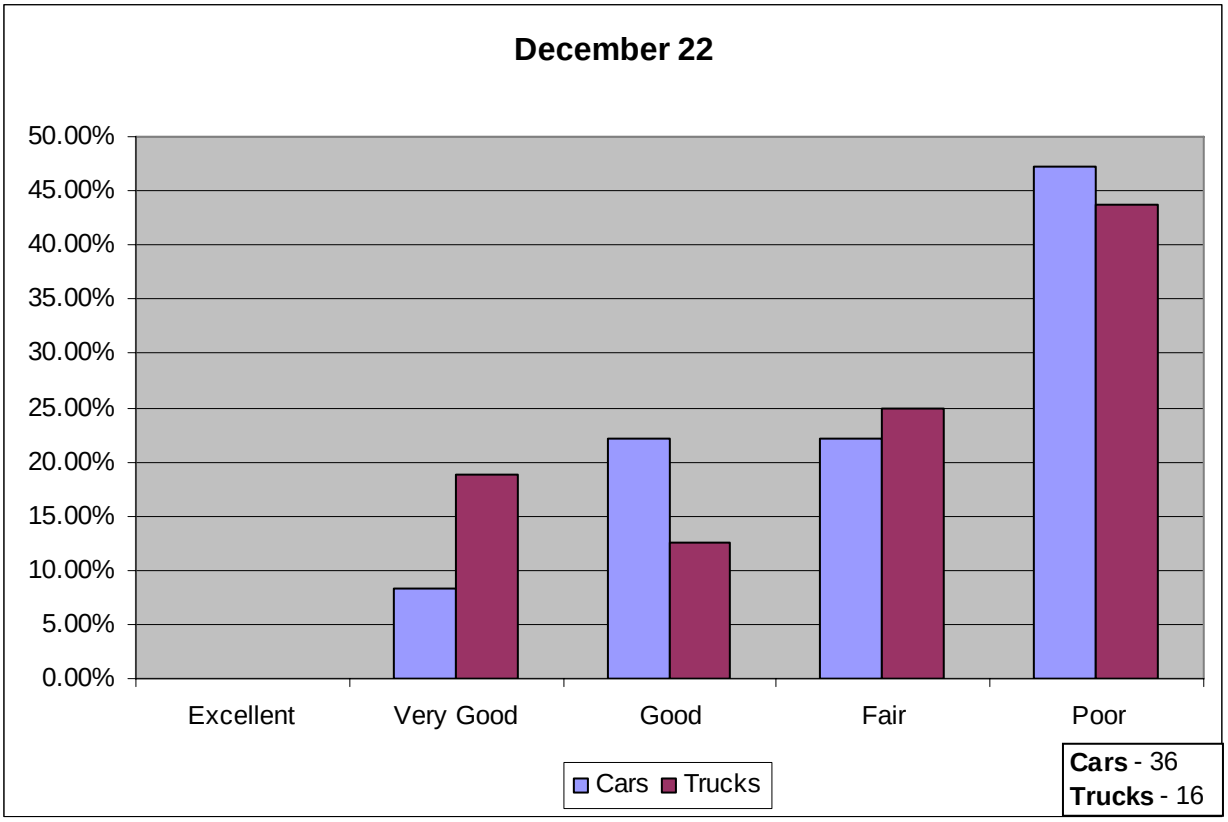

Figure 57: Rating of the Road Clearing and Treatment on December 22, 2004.

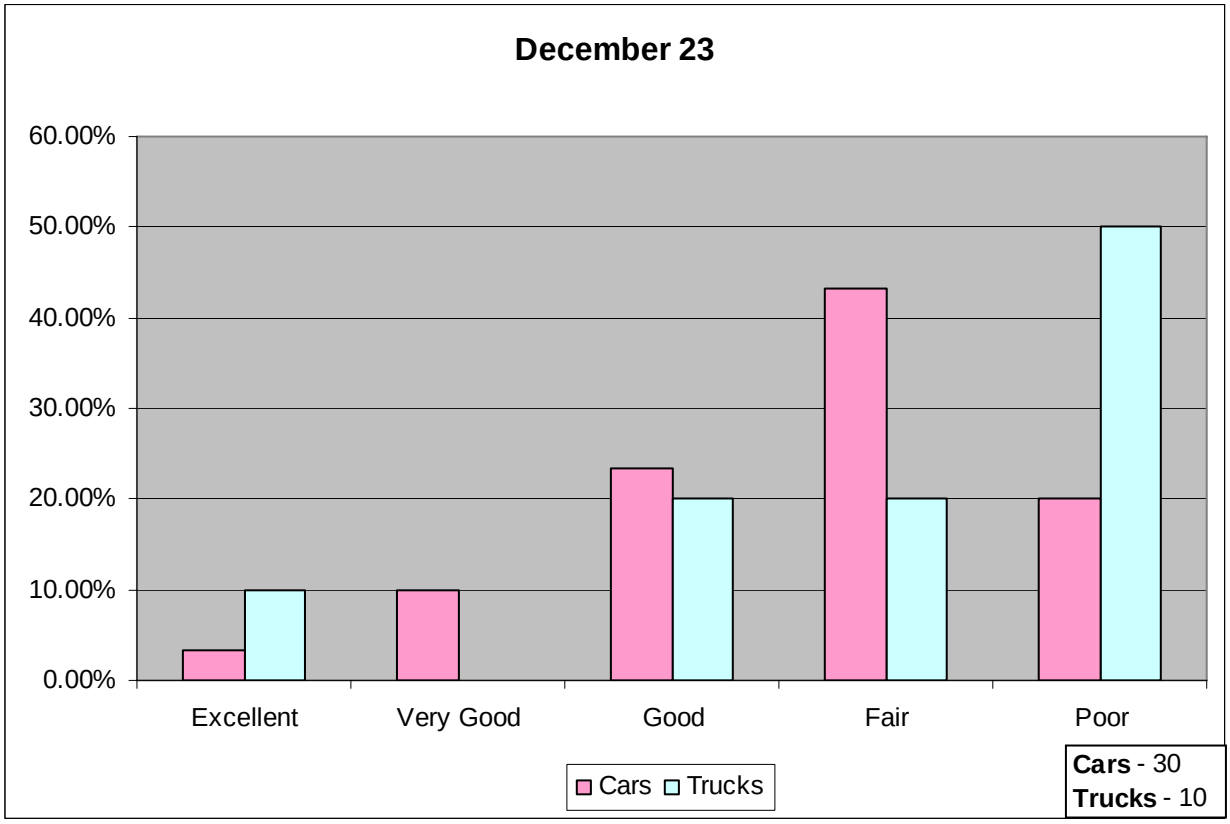

Figure 58: Rating of the Road Clearing and Treatment on December 23, 2004.

Question 15

In question 15, the drivers were asked to rank the stress factors which they experienced during their travel for the last few miles. As with question 10, some drivers instead of ranking the factors checked all the stress factors that they experienced. In such cases equal weighting was given to all the selected factors. However, responses were different for both days. On the 22nd, most respondents considered driving stressful because of the snow on the highway in the driving lane. But on December 23, most drivers experienced stress because of the icy conditions in the driving lane. Table 35 represents the total responses of drivers who experienced stress. Table 36 and Table 37 show the ranking of the stress factors experienced by the drivers on December 22 and December 23 respectively.
Table 38 represents the total responses of car and truck drivers who experienced stress on both the days. Table 39 and Table 40 show the ranking of the stress factors experienced by the car and truck drivers respectively on December 22. Similarly, Table 41 and Table 42 show the ranking of stress factors for both car and truck drivers on December 23.

Table 35. Responses about the Stress Factors Drivers Experienced.

Date		12/22/2004	12/23/2004
		# Respondents	# Respondents
Stress factors experienced in the last few miles or so of your drive:	Not stressful, similar to normal driving	11	5
	Stressful because of falling snow or other precipitation	19	5
	Stressful because of blowing snow and reduced visibility	10	5
	Stressful because of the traffic around you	21	14
	Stressful because of fog	1	0
	Stressful because of the snow on the highway in your driving lane	30	14
	Stressful because of the icy conditions in your driving lane	18	28

Table 36. Ranking of Stress Factors which Drivers Experienced on December 22, 2004.

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	10	1	0	0	0	0	0
Stressful because of falling snow or other precipitation	10	5	3	1	0	0	0
Stressful because of blowing snow and reduced visibility	7	1	2	0	0	0	0
Stressful because of the traffic around you	5	11	3	0	2	0	0
Stressful because of fog	0	0	0	0	0	1	0
Stressful because of the snow on the highway in your driving lane	24	3	3	0	0	0	0
Stressful because of the icy conditions in your driving lane	9	6	1	2	0	0	0

Table 37. Ranking of Stress Factors which Drivers Experienced on December 23, 2004.

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	5	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	2	1	1	1	0	0	0
Stressful because of blowing snow and reduced visibility	1	3	1	0	0	0	0
Stressful because of the traffic around you	5	6	3	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	7	6	0	0	1	0	0
Stressful because of the icy conditions in your driving lane	20	8	0	0	0	0	0

Table 38. Responses about the Stress Factors Car and Truck Drivers Experienced.

Dates		12/22/2004		12/23/2004	
Vehicle Type		Cars	Trucks	Cars	Trucks
		#	#	#	#
Stress factors experienced in the last few miles or so of your drive:	Not stressful, similar to normal driving	7	4	4	1
	Stressful because of falling snow or other precipitation	16	3	2	3
	Stressful because of blowing snow and reduced visibility	9	1	4	1
	Stressful because of the traffic around you	14	7	10	4
	Stressful because of fog	1	0	0	0
	Stressful because of the snow on the highway in your driving lane	21	9	11	3
	Stressful because of the icy conditions in your driving lane	15	3	21	7

Table 39. Ranking of Stress Factors which Car Drivers Experienced on December 22, 2004.

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	6	1	0	0	0	0	0
Stressful because of falling snow or other precipitation	8	4	3	1	0	0	0
Stressful because of blowing snow and reduced visibility	6	1	2	0	0	0	0
Stressful because of the traffic around you	2	7	3	0	2	0	0
Stressful because of fog	0	0	0	0	0	1	0
Stressful because of the snow on the highway in your driving lane	17	3	1	0	0	0	0
Stressful because of the icy conditions in your driving lane	7	5	1	2	0	0	0

Table 40. Ranking of Stress Factors which Truck Drivers Experienced on December 22, 2004.

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	4	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	2	1	0	0	0	0	0
Stressful because of blowing snow and reduced visibility	1	0	0	0	0	0	0
Stressful because of the traffic around you	3	4	0	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	7	0	2	0	0	0	0
Stressful because of the icy conditions in your driving lane	2	1	0	0	0	0	0

Table 41. Ranking of Stress Factors which Car Drivers Experienced on December 23, 2004.

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	4	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	1	0	0	1	0	0	0
Stressful because of blowing snow and reduced visibility	1	2	1	0	0	0	0
Stressful because of the traffic around you	4	4	2	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	6	4	0	0	1	0	0
Stressful because of the icy conditions in your driving lane	14	7	0	0	0	0	0

Table 42. Ranking of Stress Factors which Truck Drivers Experienced on December 23, 2004.

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	1	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	1	1	1	0	0	0	0
Stressful because of blowing snow and reduced visibility	0	1	0	0	0	0	0
Stressful because of the traffic around you	1	2	1	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	1	2	0	0	0	0	0
Stressful because of the icy conditions in your driving lane	6	1	0	0	0	0	0

Question 16

The drivers were asked about how difficult it was to drive the last few miles during the storm. More than half of the drivers surveyed felt it was moderately difficult to drive on I-271 Southbound. Over three-fourths of the drivers rated the driving was moderately difficult or very difficult on both days.

Table 43 gives the number of responses and percentages and Figure 59 represents them graphically for all drivers. Table 44 gives the number of responses and percentages for car and truck drivers separately. Figure 60 and Figure 61 represents them graphically for December 22 and 23 respectively.

Table 43. Responses on Difficulty of Driving on I-271 Southbound.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
How difficult was it to drive the last few miles or so of this freeway?	Not difficult	2	3.85%	1	2.50%
	Just a bit more difficult than under clear and dry conditions	9	17.31%	5	12.50%
	Moderately difficult	27	51.92%	27	67.50%
	Very difficult	14	26.92%	7	17.50%

Table 44. Responses on Difficulty of Driving on I-271 Southbound (car and truck driver responses separated).

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How difficult was it to drive the last few miles or so of this freeway?	Not difficult	2	5.56%	0	0.00%	1	3.33%	0	0.00%
	Just a bit more difficult than under clear and dry conditions	4	11.11%	5	31.25%	4	13.33%	1	10.00%
	Moderately difficult	21	58.33%	6	37.50%	22	73.33%	5	50.00%
	Very difficult	9	25.00%	5	31.25%	3	10.00%	4	40.00%

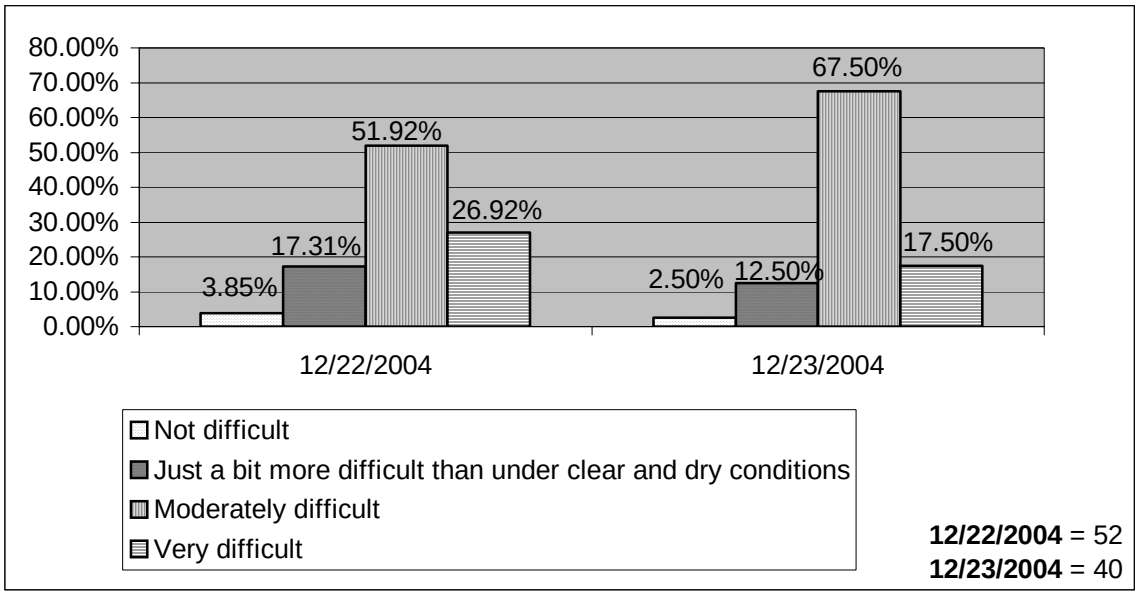

Figure 59: Response Percentages of Drivers about Driving Difficulty.

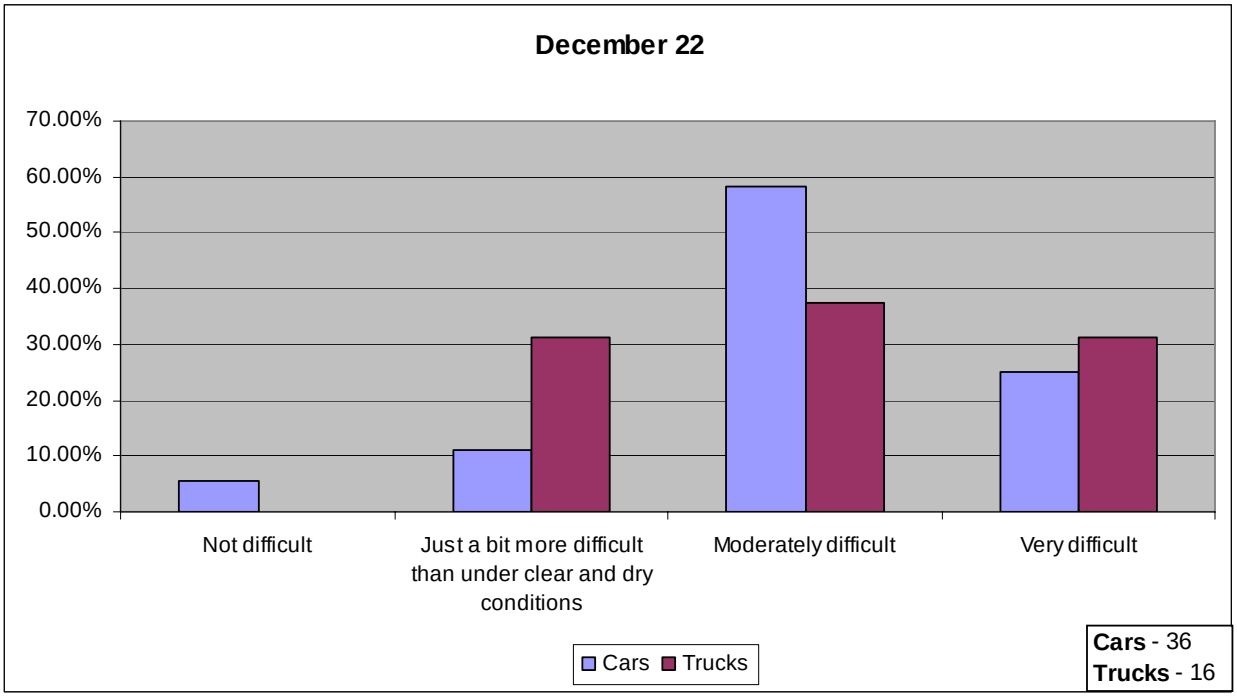

Figure 60: Response Percentages of Drivers about Driving Difficulty on December 22, 2004.

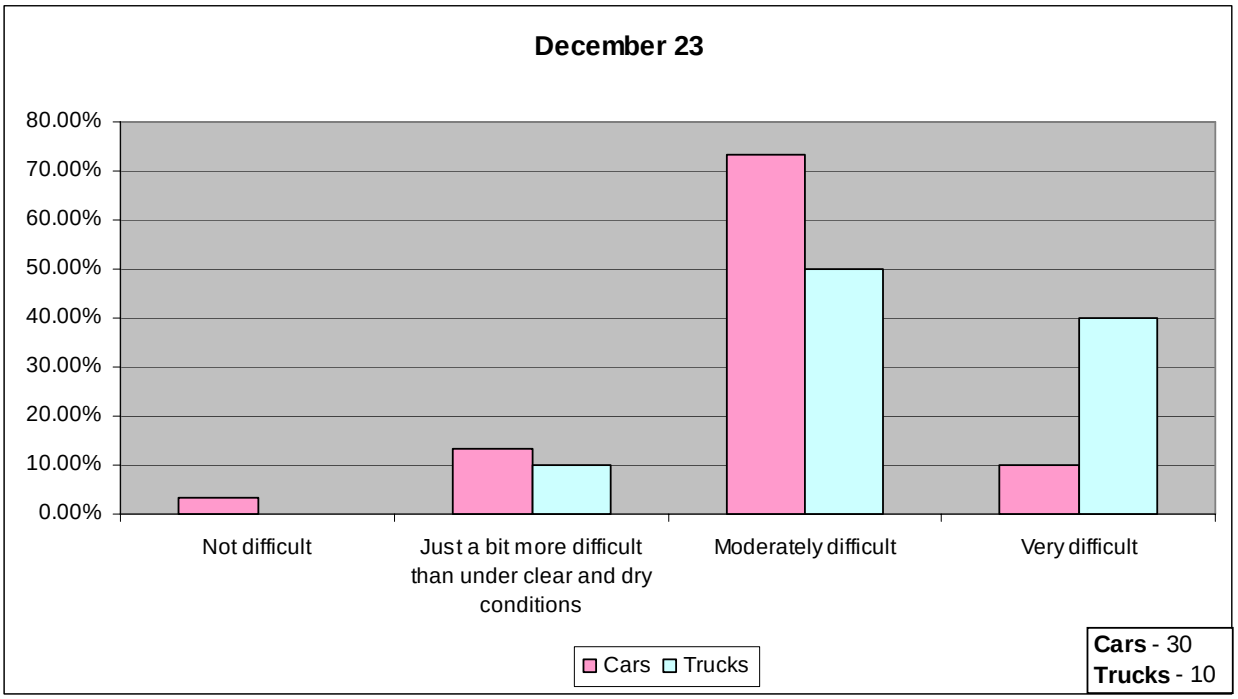

Figure 61: Response Percentages of Drivers about Driving Difficulty on December 23, 2004.

Question 17

Question 17 asked how safe the drivers felt when they drove on the freeway for the last few miles during the storm. On December 22, about 39% of car drivers said that they felt moderately safe while driving on I-271 Southbound and 38% of truck drivers said that they were just a little bit less safe than under clear and dry conditions. On 23rd, high percentage of drivers replied that they felt moderately safe. On both the days' clear majority of drivers felt either unsafe or moderately safe driving. Table 45 gives the number of responses and percentages and Figure 62 represents them graphically for all drivers. Table 46 gives the number of responses and percentages for car and truck drivers separately. Figure 63 and Figure 64 represents them graphically for both the days.

Table 45. Responses on How Safe the Drivers Feel while Driving on I-271 Southbound.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
How safe do you feel driving the last few miles or so of this freeway?	Very safe	5	9.62%	3	7.50%
	Just a bit less safe than under clear and dry conditions	15	28.85%	7	17.50%
	Moderately safe	19	36.54%	23	57.50%
	Not safe	13	25.00%	7	17.50%

Table 46. Responses on How Safe the Drivers Feel while Driving on I-271 Southbound.

Dates		12/22/2004				12/23/2004			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How safe do you feel driving the last few miles or so of this freeway?	Very safe	4	11.11%	1	6.25%	3	10.00%	0	0.00%
	Just a bit less safe than under clear and dry conditions	9	25.00%	6	37.50%	6	20.00%	1	10.00%
	Moderately safe	14	38.89%	5	31.25%	16	53.33%	7	70.00%
	Not safe	9	25.00%	4	25.00%	5	16.67%	2	20.00%

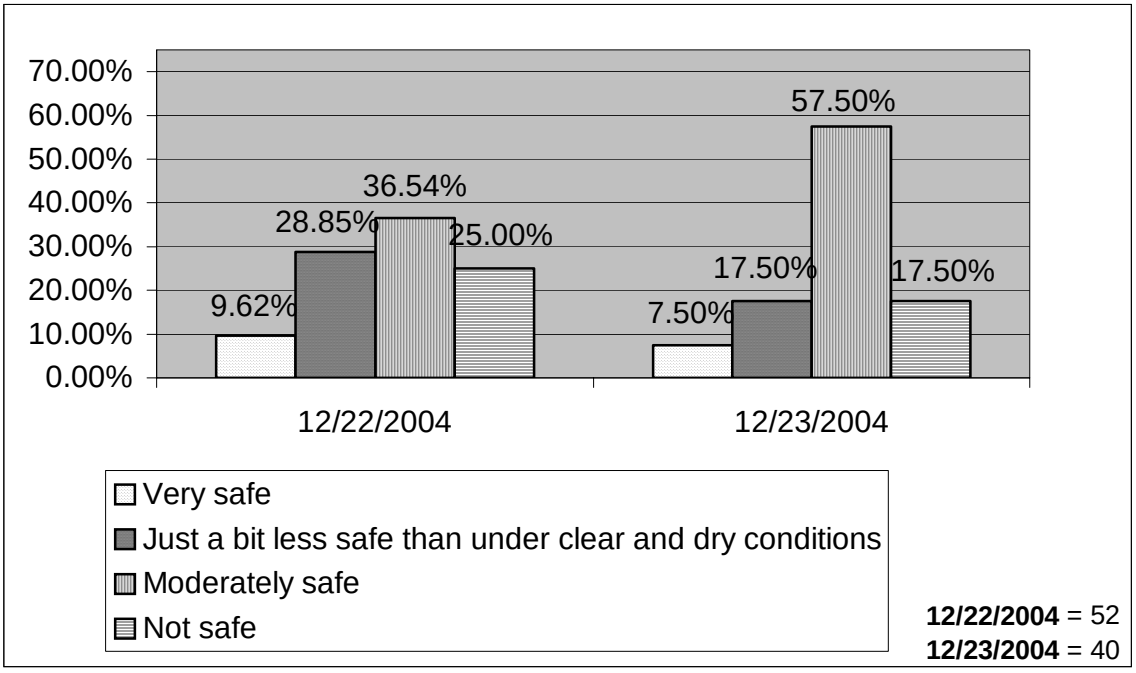

Figure 62: Response Percentage of How Safe the Drivers feel Driving on I-271.

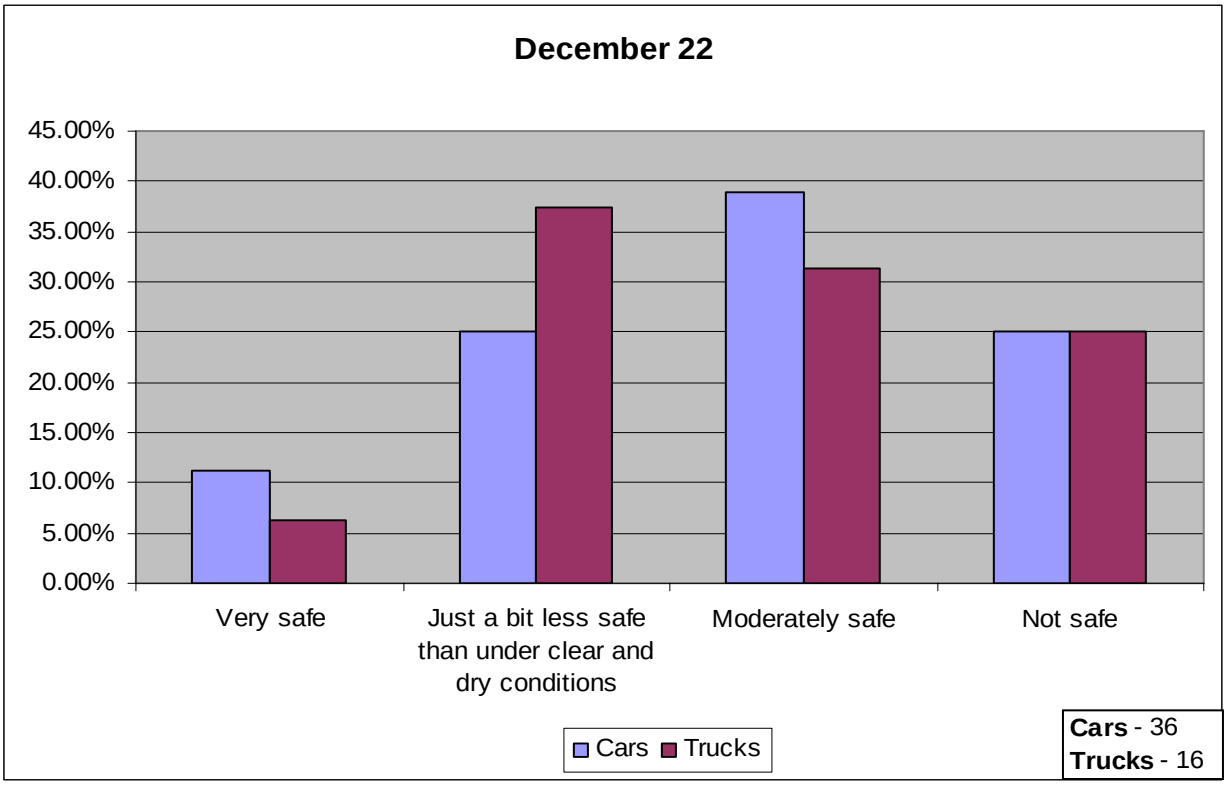

Figure 63: Response Percentages of How Safe the Car and Truck Drivers feel Driving on I-271 on December 22, 2004.

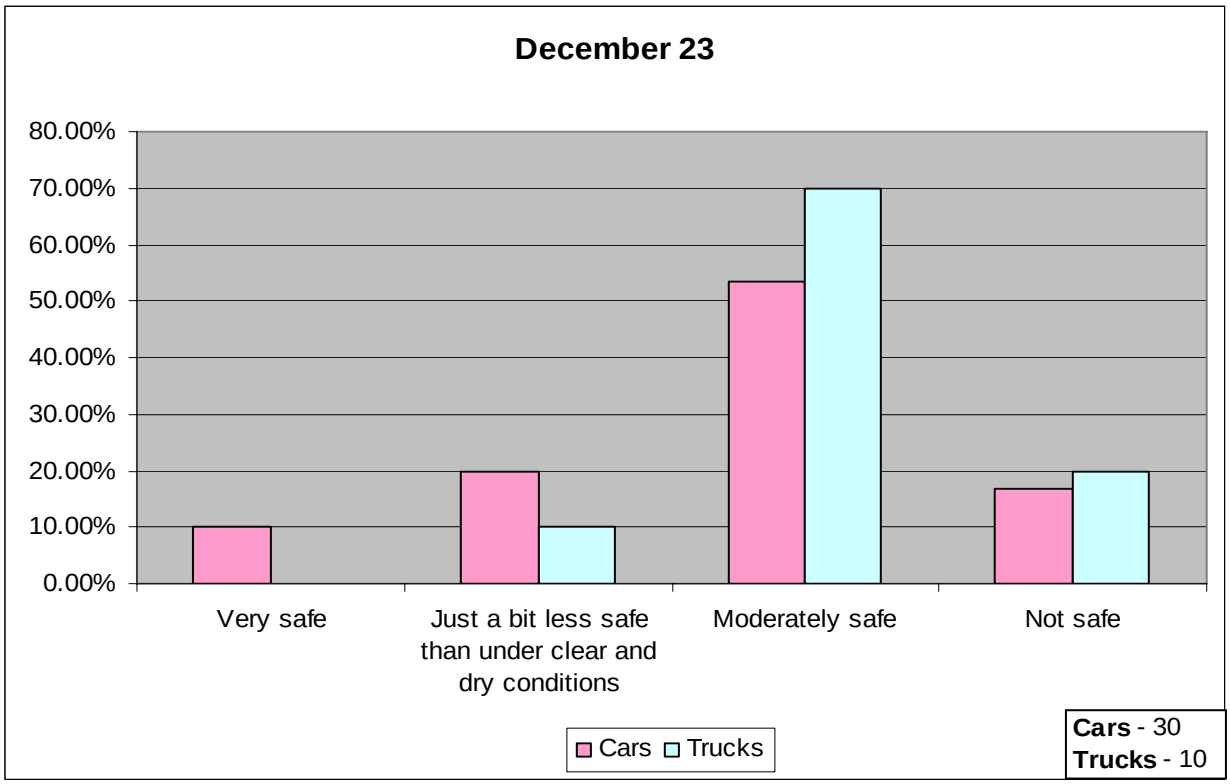

Figure 64: Response Percentages of How Safe the Car and Truck Drivers feel Driving on I-271 on December 23, 2004.

7. DISCUSSION OF RESULTS & CONCLUSIONS FOR SURVEY ON I-271

The driver survey at the rest area 04-440 on I-271 near Richfield was successfully conducted and evaluated. The procedure followed during the survey worked quite well as the response rate was good and most of the drivers were cooperative in answering the questions providing their valuable time. It was observed that driving and weather conditions were pretty bad on the 22nd and 23rd of December, 2004. This can be seen in the reduced speeds of drivers who were aware of the potential hazardous conditions prevailing on the road. Conditions were even worse to the South and the West where level III snow emergencies were declared in numerous counties. It should be noted that this snow storm was a fairly severe snow storm. Due to the lack of winter storms during the 2004, 2005 and 2006 years additional driver surveys could not be conducted in less severe or under more normal winter storm conditions during the duration of the study to obtain data for a more balanced set of winter storm and snow conditions.

The RWIS speed and surface temperature graphs obtained from station number 68 provided in the previous sections give an insight to the conditions on I-271 Southbound. As the road conditions deteriorated almost all of the drivers reduced their speed considerably on the 22nd and 23rd. The surface temperature also fell below 32°F over a period of more than 18 hours. The plots from the National Climatic Data Center (NCDC) show that there was considerable snowfall in the region on the 22nd and 23rd. The data obtained from RWIS sensors (Station No. 68) were not accurate as observed in the graphs. The RWIS sensors reported the number of vehicles passing through as more than 100 or 150 vehicles in a given 5 minute time interval. This is probably caused by the pavement sensors reporting data intermittently. If a pavement sensor cannot report data during a five-minute interval, it continues counting vehicles and sends the total count when it can, thus a large count may represent an accumulation over several 5 minute periods. This made it not feasible to use RWIS traffic volume as a factor in the determination of the level of service. Also the RWIS surface temperature data may not be accurate as some of the values remain at the same temperature for an extended period of time.

The pictures taken on both days documented that the typical condition of the road was covered with snow and/or ice. Though wheel tracks were visible on both days the primary concern for drivers was the slippery road surface and some lack of visibility due to falling snow on both days and freezing rain on the 23rd. This caused the drivers to reduce their speed. However, things started to improve towards December 23 with more clearing of the roads and better weather conditions.

The survey respondents were mainly male. 16% of the car drivers responded to the survey was female and all of the truck drivers surveyed were male. The car drivers have been driving for 28 years on the average and the truck drivers have been driving 17 years on the average. About 50% of the car drivers were not familiar with this stretch of the road whereas only 15% of the truck drivers were not familiar with this stretch of the road. About 60-70% of the respondents were driving an automobile or SUV, and a quarter of them drove tractor trailers. The remaining drivers were driving pick-up trucks and large trucks. 70-75% of the car drivers used two-wheel drive while only 25-30% used four-wheel drive. About 70% of the truck drivers used the drive system available within the trucks. Almost everyone had their headlights on irrespective of the period of time. It was noted that most of the drivers drove in the right lane, around 70-75% of car drivers on both the days, 94% of truck drivers on December 22 and 60% of truck drivers on December 23. About 25-30% of car drivers and 20% of truck drivers drove in the left lane. Most respondents drove well below the speed limit irrespective of the type of vehicle they

were driving because of the severe weather and road conditions. However, about 30% of the truck drivers on December 22 drove about the speed limit. On the 22nd the car drivers were driving slower than the truck drivers whereas on the 23rd the car drivers were driving faster than

the truck drivers. The main factors opined for the reduced speed were the snow and ice on roads along with the somewhat reduced visibility on 22nd both for the car and truck drivers. On 23rd the road surface conditions were the main factors that affected the driving speed of the car and truck drivers. 92% of the car drivers and 75% of the truck drivers opined that the pavement was 60% or less clear from edgeline to edgeline on the 22nd as the roads were covered with snow and 83% of car drivers and 90% of truck drivers opined that the pavement was 60% or less clear from edgeline to edgeline on the 23rd as the roads were covered with snow mixed with ice and slush. Because of the above factors it was hard to drive, but the wheel tracks were visible to most drivers. About 35-40% of the car drivers replied that they could see the wheel tracks in the right or driving lane only while 70-80% of truck drivers replied that they could see wheel tracks in both the lanes, which can be confirmed by the pictures shown before.

Most of the drivers surveyed were of the opinion that the clearing and treatment of the roads was not as good as they expected or wanted. On the 22nd, 47% of the car drivers and 43% of the truck drivers opined that the clearing and treatment of the road was poor whereas on the 23rd, 20% of the car drivers and 50% of the truck drivers opined that the clearing and the treatment of the road was poor. It can be noted from the previous observation made that the frequency of snow trucks was less and that they were not on the roads much earlier than they should have been on the 23rd. However, the severity was less on the second day as the weather improved and more snow trucks passed by. Some drivers even thought that the clearing was very good on the 23rd.

The slippery road conditions made driving stressful as indicated by the results. On the 22nd both the car and truck drivers opined that the driving was stressful because of the snow on the highway and on 23rd both of the driver groups opined that the driving was stressful because of the icy conditions on the highway. More people responded that they experienced stress because of snow, ice, and lack of visibility in their driving lane. Therefore, the largest percentage of drivers replied that it was difficult to drive on the roads and that they felt that these conditions were not safe or only moderately safe for driving. The results also showed that more truck drivers found driving very difficult than car drivers.

The results over the two-day period show that there was some consistency between both days. Also, the responses by car and truck drivers were not significantly different. The graphs show similar response percentages for all questions. However, on the first day drivers indicated they had more problems with snow, while on the second the road surface was judged to be icy. All the results correlate to the graphs from RWIS, NCDC and the pictures shown before.

This driver survey performed in the winter storm provided insight into the driver speeds and their relationship with the clearing and maintenance of the roads. As the road conditions deteriorated, the drivers felt less secure and considerably decreased their speeds. When these conditions prevail, good maintenance and clearing of the roads promptly would improve driver safety and their confidence. This helps in maintaining the traffic flow continuously without considerably reducing their driving speeds.

8. PROCEDURE FOR DRIVER SURVEY AT REST AREA 04-36 ON I-76 WESTBOUND IN PORTAGE COUNTY ON JANUARY 22 2005 (7:15 AM – 6:30 PM)

The driver survey on I-76 was conducted according to the same procedure used for the driver survey on I-271.The survey was conducted at Rest Area 04-36 on I-76 Westbound in Portage County on January 22 2005. Figure 65 shows the map where the survey was conducted. Cleveland and Akron were the nearest stations where the weather data can be obtained. The Figure 66 shows the setup for the survey. The rest area was located 3.08 miles away the entrance ramp from state road 225.The drivers were driving for at least 3 miles before they stopped at the rest area so that they have enough perception of the pavement ,driving conditions and the perceived level of service.

8.1 Driver Survey Conducted at rest area 04-36on I-76 Westbound In Portage county On January 22 2005 (7:15 AM – 6:30 PM)

Figure 65: Map showing Cleveland, Akron and the rest area location where the survey was conducted.

Figure 66: Setup of the survey at rest area 04-36 on I-76 westbound.

The survey was started on January 22, 2005 at 7.15 AM. The survey procedure was to provide the respondent with the questionnaire titled "Ohio Department of Transportation Winter Maintenance Driver Survey", shown in Appendix B containing a series of questions posed to drivers about their experience driving in the snowstorm. Most of the respondents were interviewed by ORITE personnel. Only a few filled out the forms by themselves.

The survey was conducted until 6.30 PM on January 22 2005. Evaluation of the study was separated into two because of the snowfall until 11.30 AM and occasionally thereafter. Therefore the results were grouped into two; one survey is taken to be from 7.15 AM until 11.30 AM and the other one is taken from 11.30 AM to 6.30 PM. On January 22 until 11.30 AM there were about 50 people coming into the rest area out of which 19 were women and after 11.30 AM there were around 55 people out of which 12 were women. These figures count everyone apparently of driving age entering the rest area building during these times, including passengers and drivers. Until 11.30 AM 19 people responded to the questions and after 11.30 AM 23 people answered the survey. Due to a weekend there was relatively lower number of drivers visiting the rest area. The response percentage until 11.30 AM was found to be 38% and after 11.30 AM it was 41.8%. The average response percentage for the whole day was 40 %.

The frequency of snow plows passing by the rest area was noted. On January 22, until 11.30 AM the snow plows passed through the rest area at around 7.15 AM, 8.15 AM and 11.53 AM and after 11.30 AM they passed by at around 3.30 PM, 4.00 PM, 4.30 PM, 5.30 PM and 6.15 PM.

The temperatures were also noted throughout the day. At 9.30 AM the temperature was -20.5°C, 10.25 AM it was -20°C, 11.45 AM it was -18°C, 12.45 PM it was -15°C, 2.00 PM it was -21°C, 3.05 PM it was -22°C, 3.40 PM it was -21°C and at 6.05 PM it was -22°C.

8.2 Speed, Weather and Vehicle Count Data from RWIS Station No. 91

RWIS data (Station No– 91) were obtained from ODOT and graphs are plotted for average speed of vehicles, surface temperature and vehicle count on I-76 Westbound for the days beginning from January 21 to 24, 2005. The graphs in the Figure 67, Figure 68 show the average speed of the vehicles over 5 minute intervals passing by the I-76 Westbound road in the driving and passing lanes respectively. It can be observed that the some of the drivers decreased their speed to 40 mph in the morning on January 22.The official speed limit on I-76 westbound was 65 mph. It should be noted that most of the data points at zero were blank in the data file indicating data from the sensor were not reported.

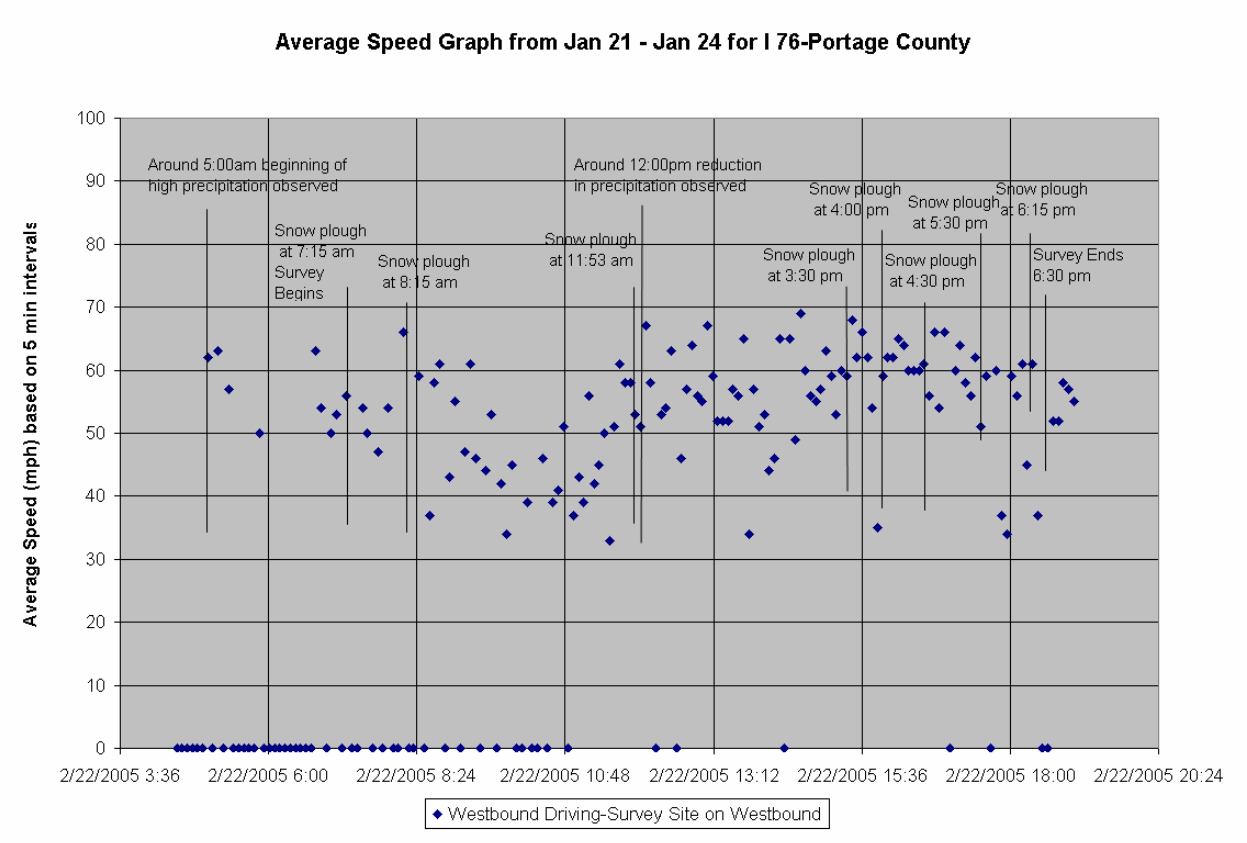

Figure 67: Plot of average speed of vehicles from RWIS data (station no. 91) for I-76 westbound driving lane.

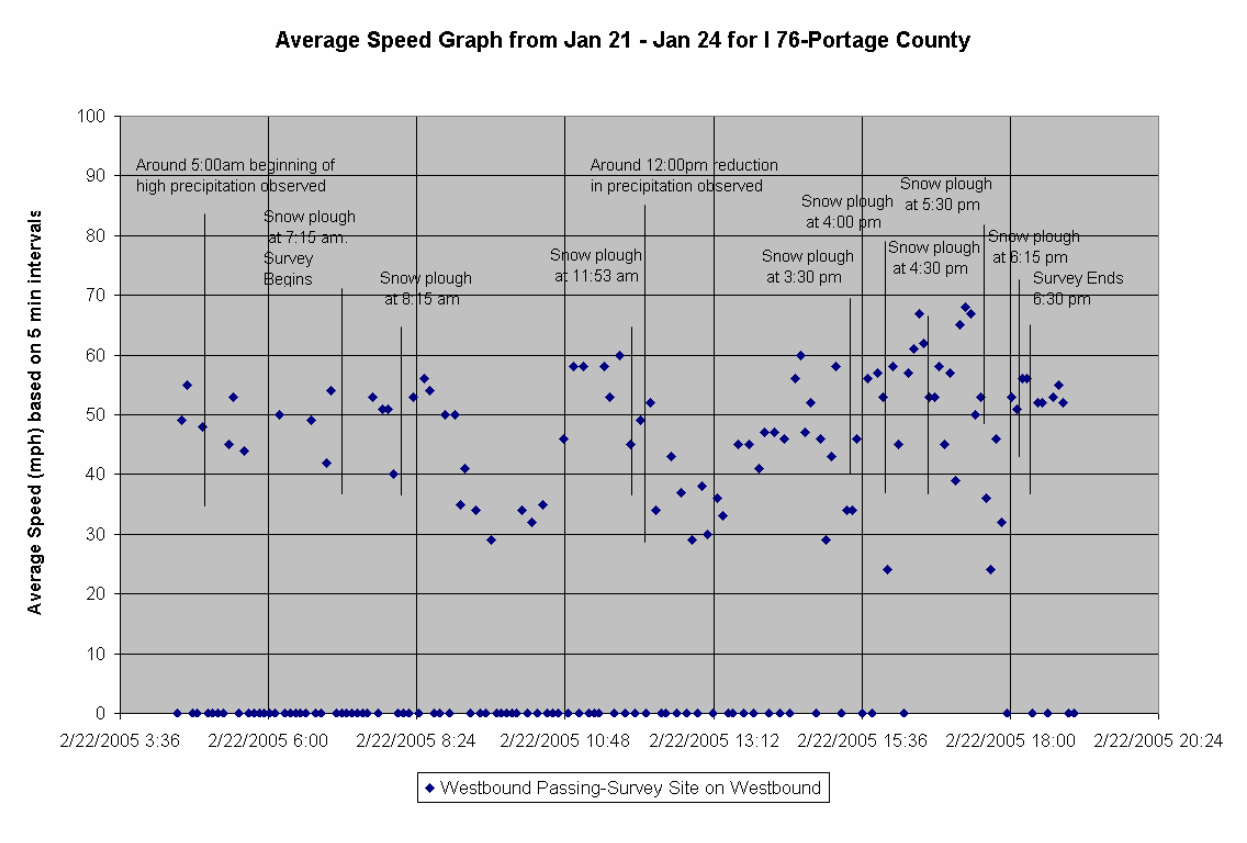

Figure 68: Plot of average speed of vehicles from RWIS data (station no. 91) for I-76 westbound passing lane.

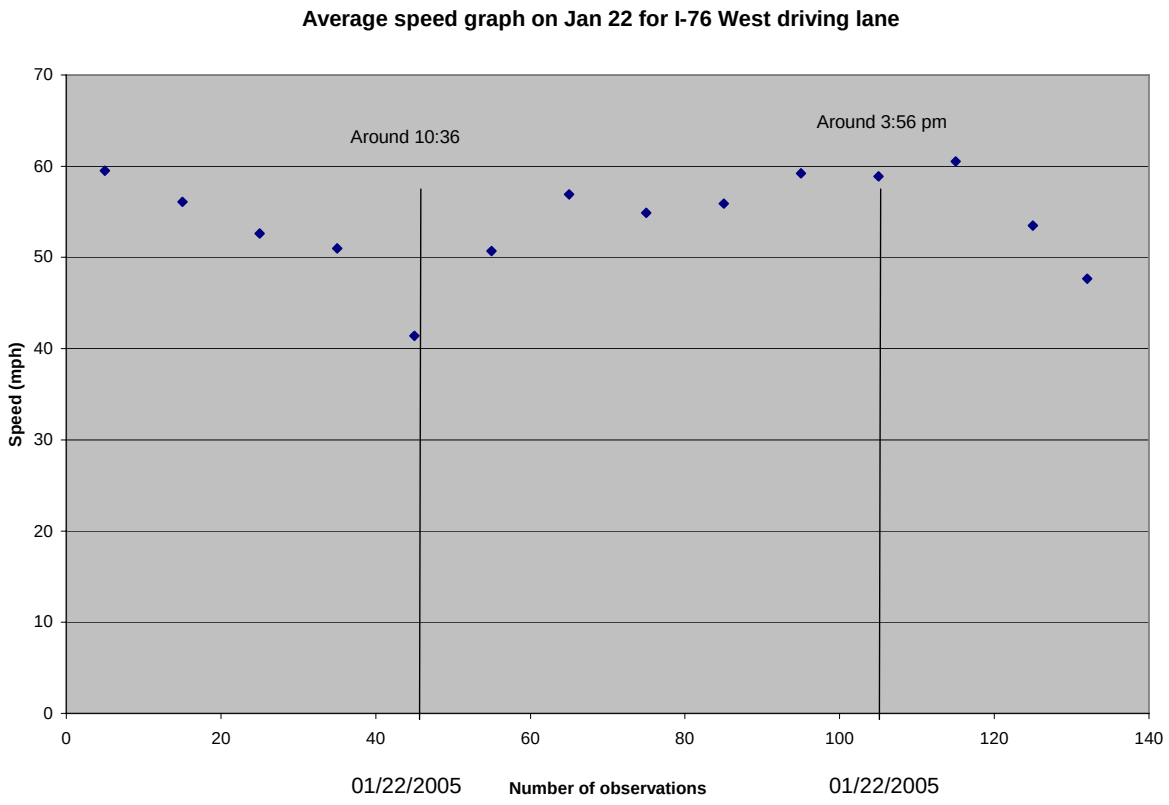

Figure 69: Plot of average speed of vehicles from RWIS data (station no. 91) for I-76 westbound driving lane.

Figure 69 and Figure 70 show the redrawn plot of average speed of vehicles from the RWIS data for I-76 West bound driving and passing lanes. All the zero values from the RWIS data were taken out and new average plots were obtained by taking average of ten consecutive speed values.

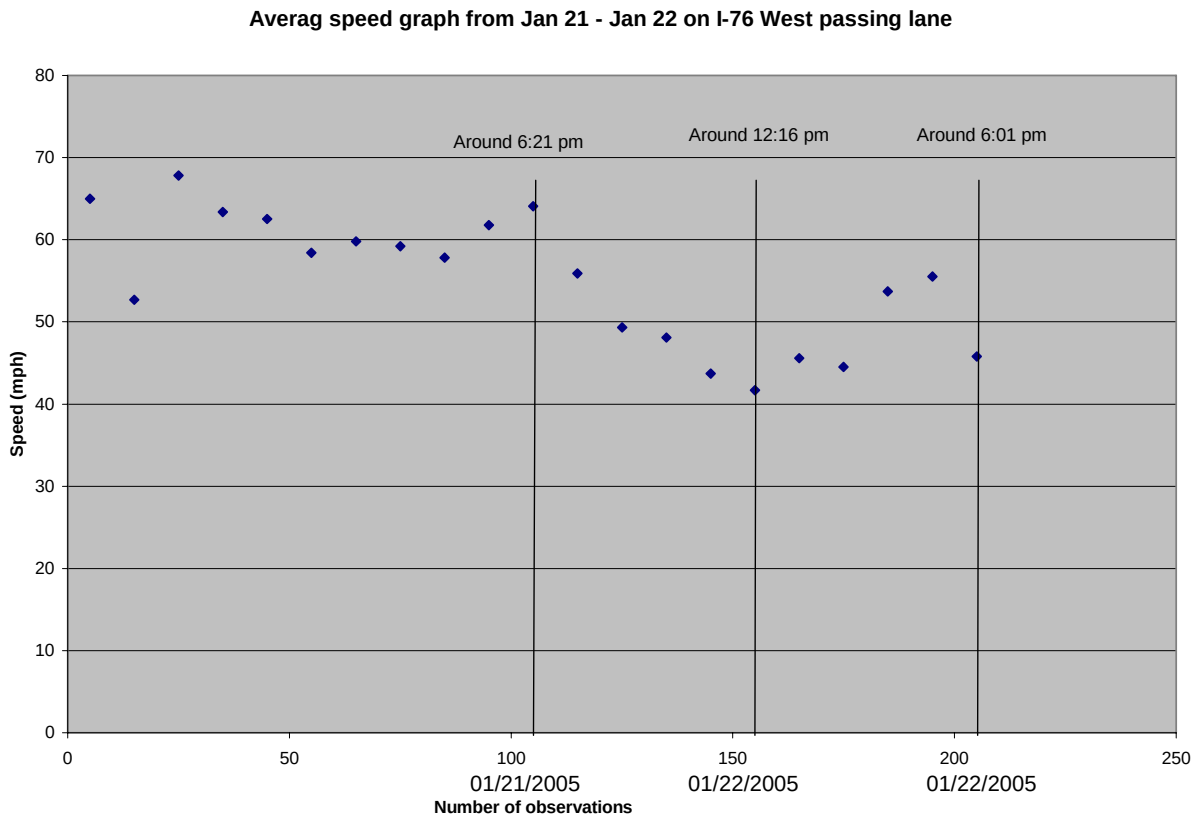

Figure 70: Plot of average speed of vehicles from RWIS data (station no. 91) for I-76 westbound passing lane.

Figure 71 and Figure 72 show the surface temperature graphs for driving and passing lanes respectively. From the surface temperature graphs it can be observed that the temperature was at or below 25ºF during the period the survey was conducted. The horizontal lines in Figure 71 and Figure 72 indicate times when the sensor was "stuck" and not actively reporting updated data.

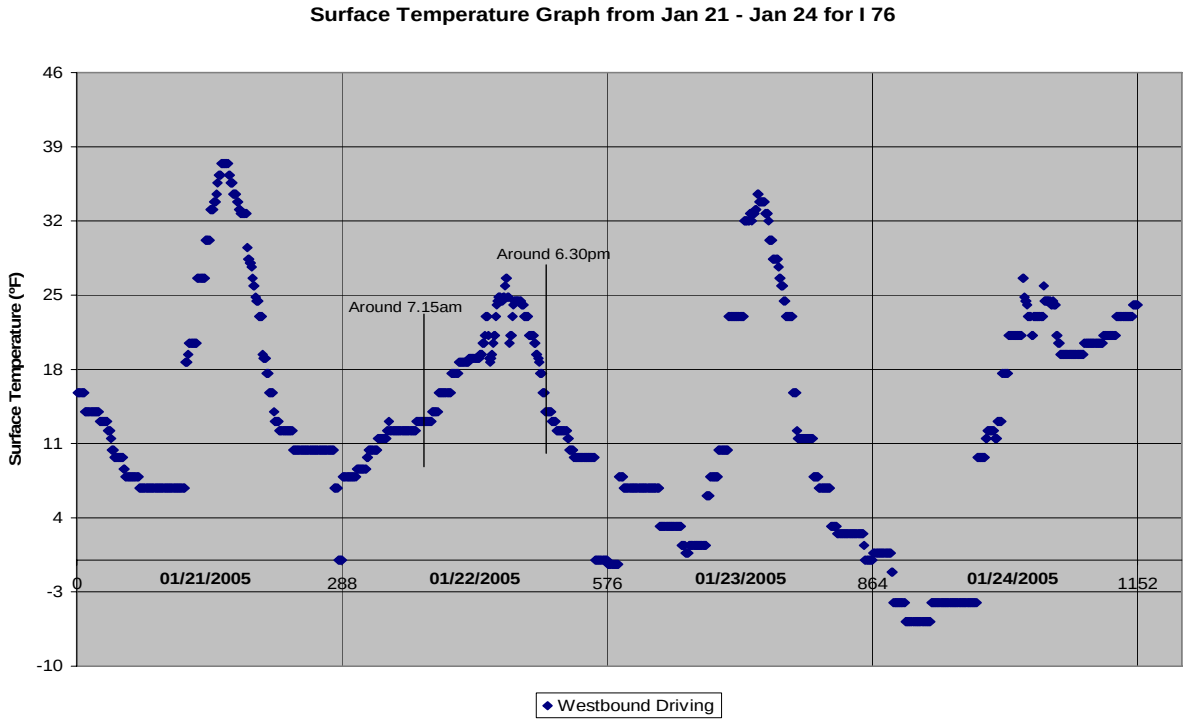

Figure 71: Plot of surface temperature from RWIS data (station no. 91) for I-76 westbound driving lane.

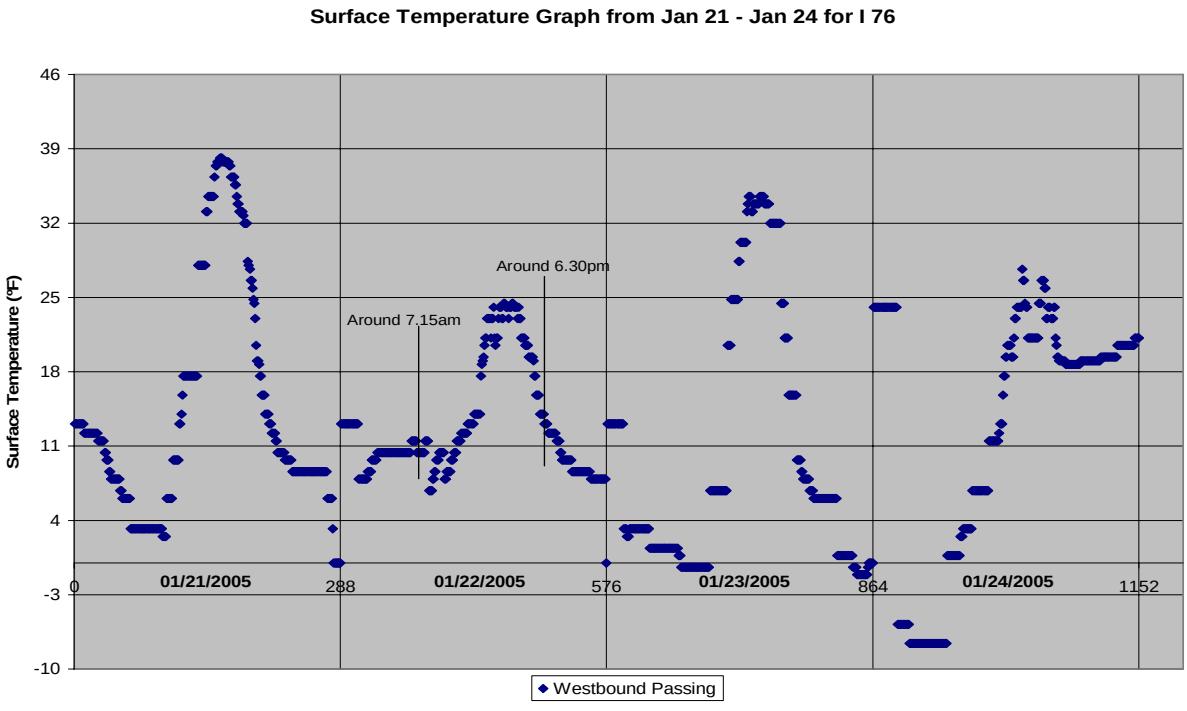

Figure 72: Plot of surface temperature from RWIS data (station no. 91) for I-76 westbound passing lane.

Figure 73 shows the air temperature graph for I-76 Westbound. One of the data reported by RWIS was around 200ºF which is incorrect. Therefore a new graph is drawn as in Figure 74 with a maximum of 50ºF. It can be observed that the air temperature was below 32ºF during the entire survey.

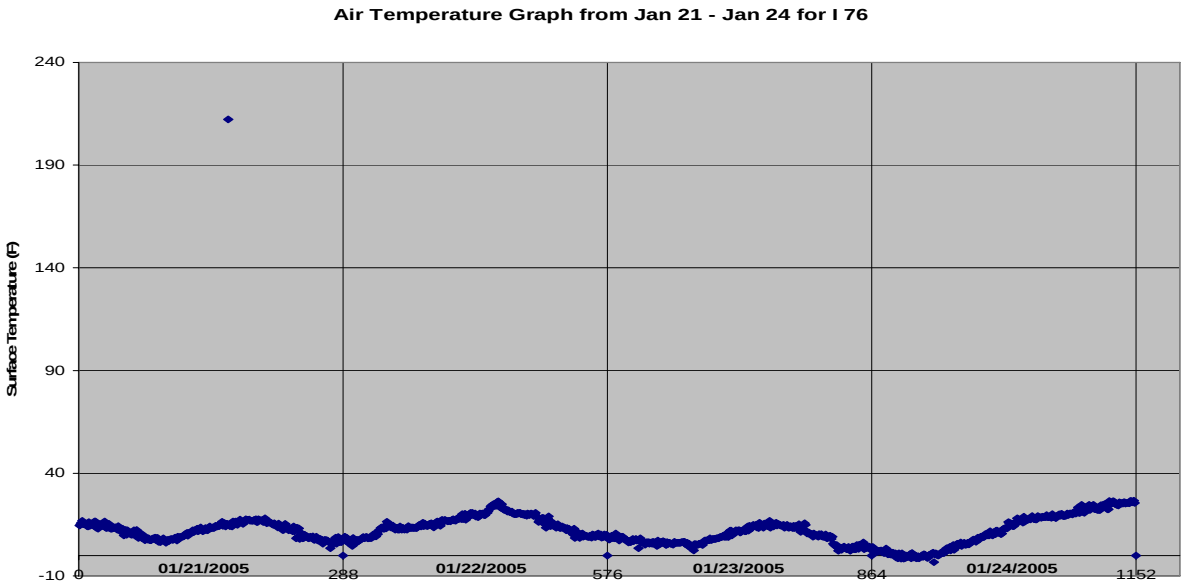

Figure 73: Plot of air temperature from RWIS data (station no. 91) for I-76.

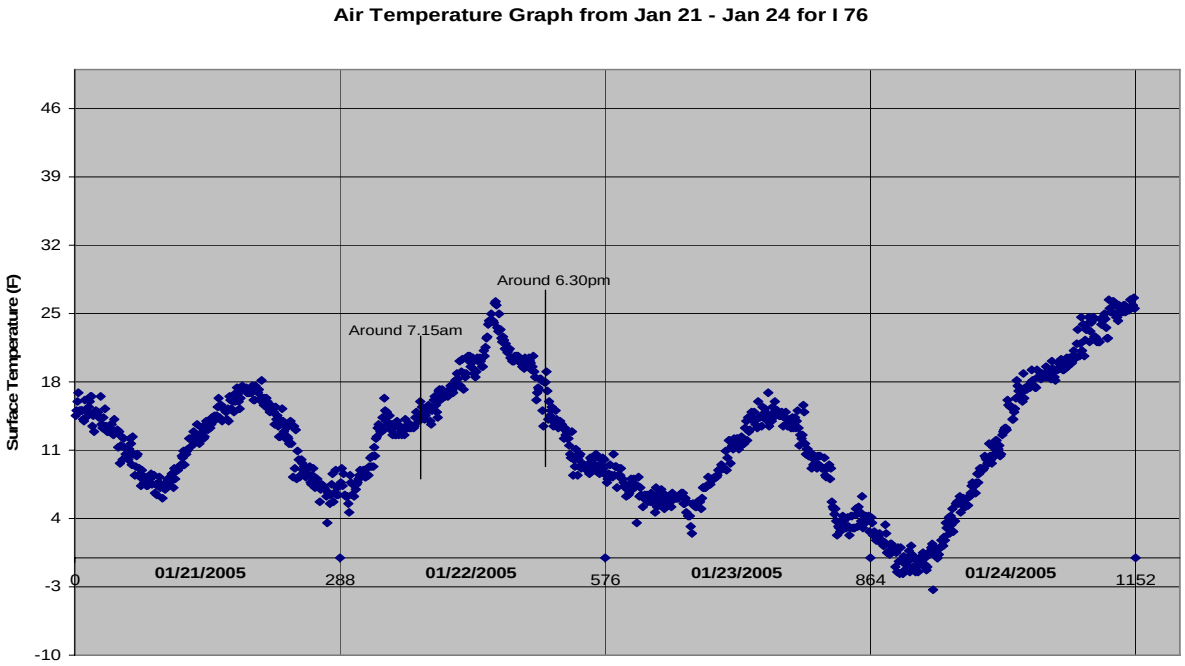

Figure 74: Plot of air temperature from RWIS data (station no. 91) for I-76 (max 50ºF).

A plot of the number of vehicles on I-76 Westbound from 21 to 24 January was done. Figure 75 and Figure 76 shows when a sensor is "stuck", it continues to continue vehicles and reports the accumulated total when it is able to communicate with the RPU again, resulting in anomalously high vehicle counts following a series of 0 values for count and speed. Thus is Figure 77 and Figure 78, the same data are re-plotted discarding all counts above 100, or one vehicle every 3 seconds, for driving and passing lanes respectively. In the passing lane on 22 January, very few vehicles drove by. Most of the vehicle used driving lane. It can be seen that the number of vehicles passing by I-76 Westbound on 22nd was considerably lower when compared to other three days.

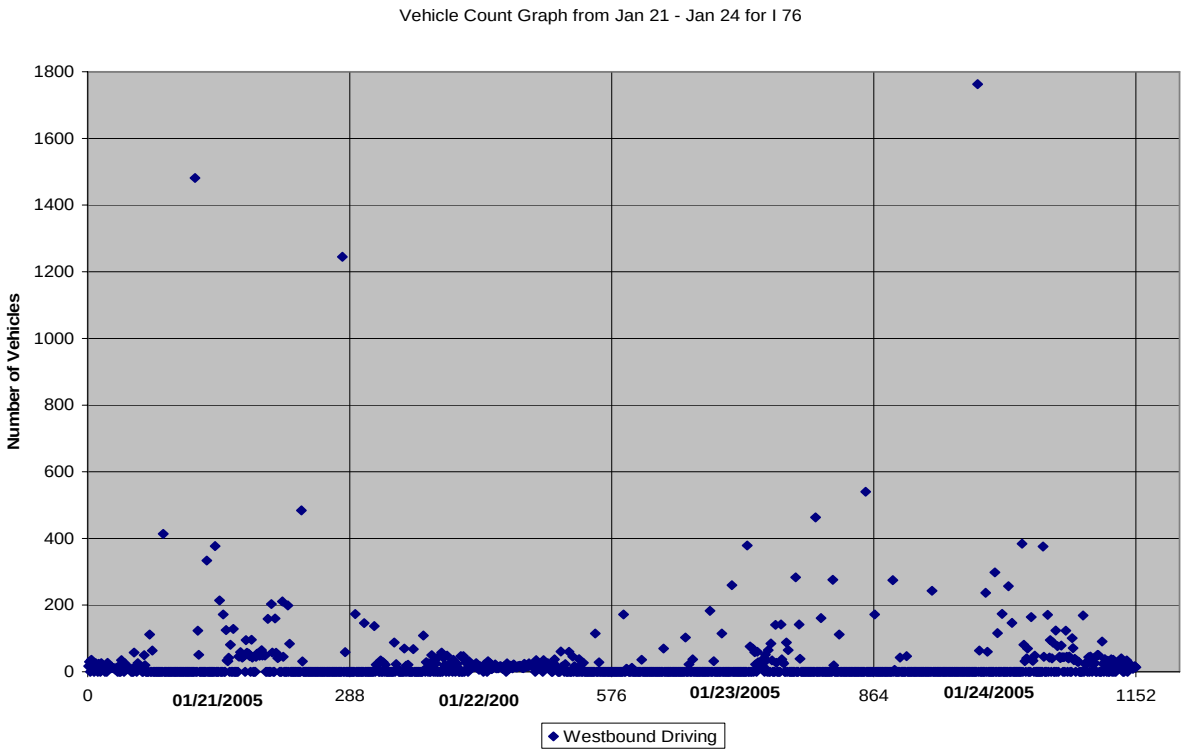

Figure 75: Plot of number of vehicles from RWIS data for I-76 driving lane (station no. 91).

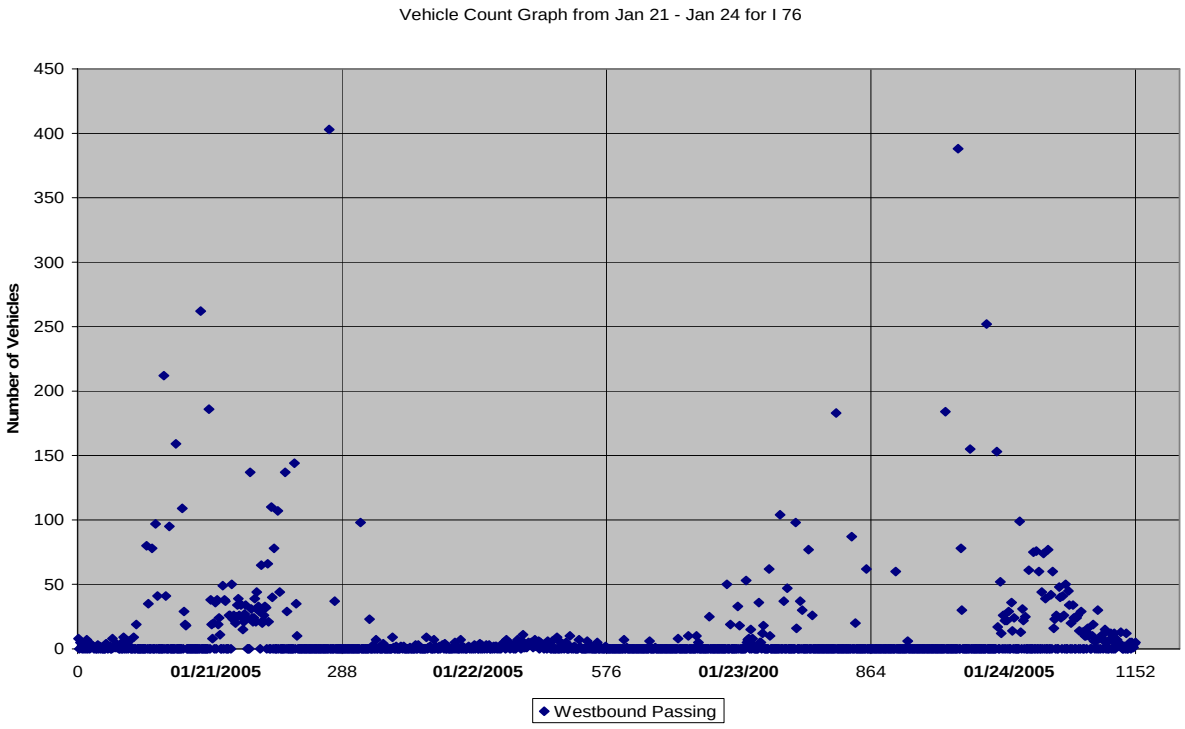

Figure 76: Plot of number of vehicles from RWIS data for I-76 passing lane (station no. 91).

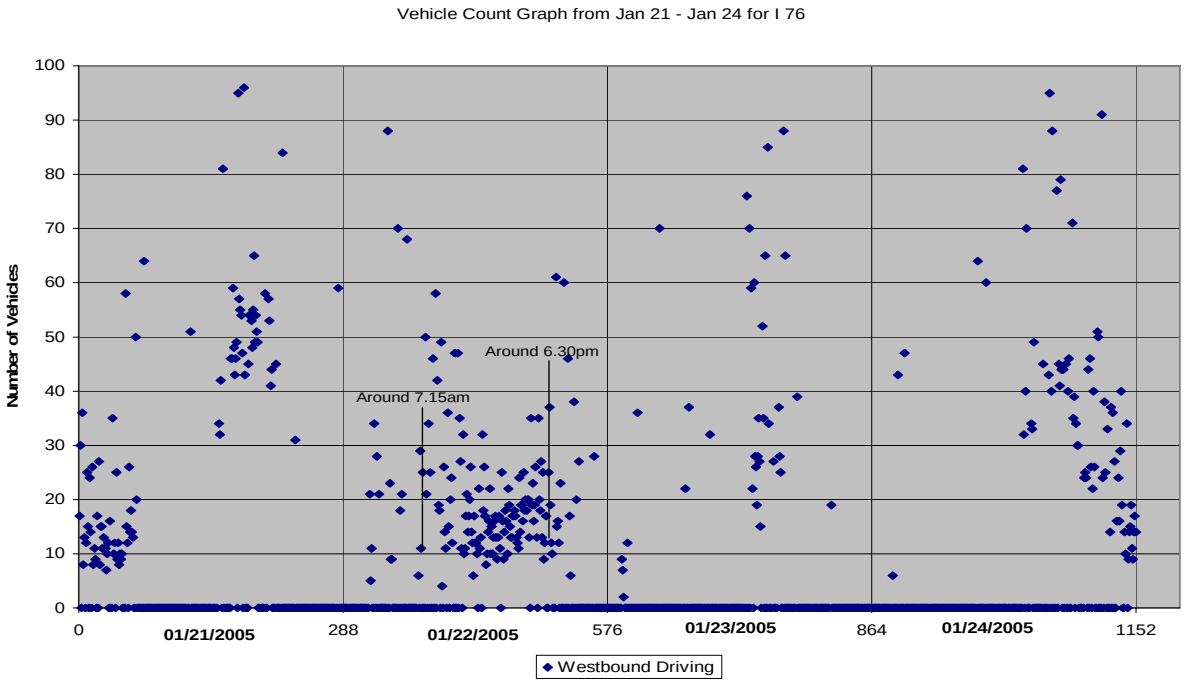

Figure 77: Redrawn plot of the number of vehicles from RWIS data (station no. 91) for I-76 westbound driving lane with maximum period count = 100.

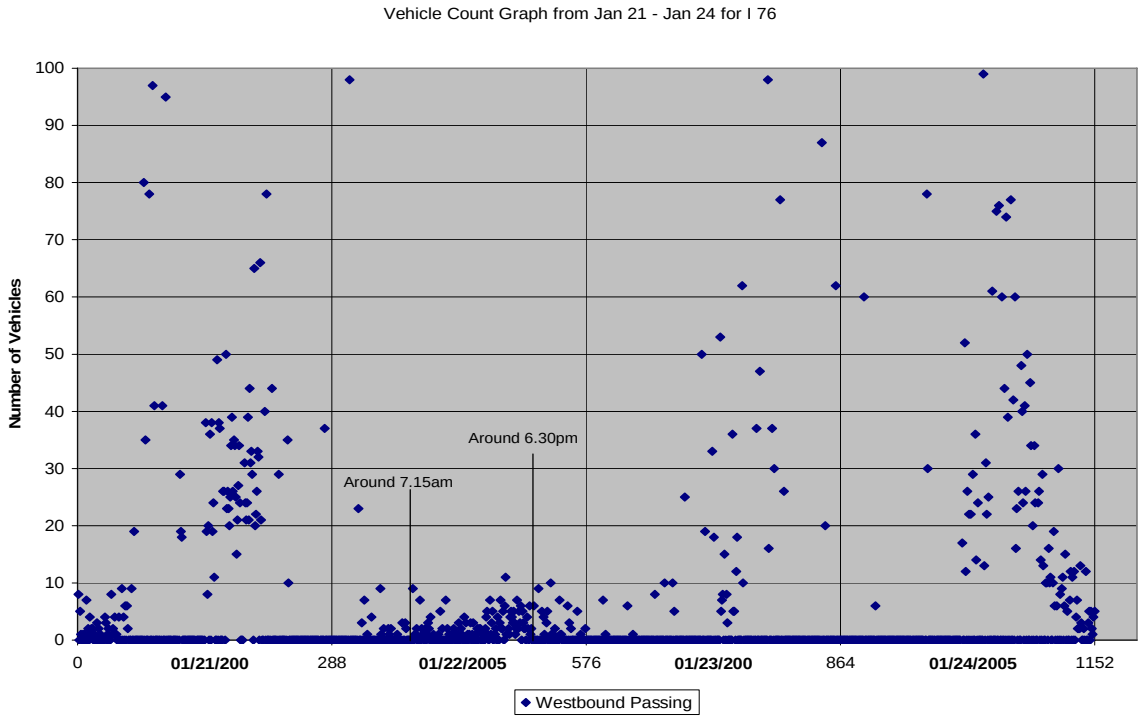

Figure 78: Redrawn plot of the number of vehicles from RWIS data (station no. 91) for I-76 westbound passing lane with maximum period count = 100.

8.3 Weather Data from National Climatic Data Center

Weather data starting from January 20 to January 24 were viewed online from the National Climatic Data Center website (http://www.ncdc.noaa.gov/). The data are unedited surface weather observations daily observations (10B form). The two closest locations where the data from the website can be observed were Akron Fulton International Airport and Cleveland Hopkins International Airport stations. Figure 79 and Figure 80 show the hourly precipitation amount (water equivalent) at stations located in Akron and Cleveland respectively between 20 and 24 January. It was reported that on the 22nd at the station in Akron there was only a traceable amount of snowfall. The traceable amount was taken as 0.005 inches (water equivalent) to show on the graph. On the same day at the Cleveland Hopkins International Airport station, there was a total of 0.43 inches (water equivalent). As seen from the map, the rest area at which the survey was conducted is located between the two stations. The snowfall at the rest area neither is intense as in Cleveland nor is mild as in Akron. The amount of snowfall can be taken as the average of the amount obtained from the two stations. From the station data obtained from Cleveland, it can be observed that the snowfall was high from 5.00am to 12.00pm on the 22nd.The RWIS precipitation data for station 91 is tabulated in Appendix D of the report. This supports the decision to separate the survey analysis into two, one until 11.30am and the other after 11.30am. The conversion of inches of water into inches of snow is highly variable and dependent on a number of factors as indicated in Snow Rain Equivalents (http://www.weatherwise.org/qr/qry.snowrainequiv.html/) and Snow (http://www.acsu.buffalo.edu/~insrisg/nature/nw99/snow.html/) articles. In some cases 5-10 inches of heavy snow converts to an inch of water while at the other extreme 30 inches of very light snow converts to only 1 inch of water.

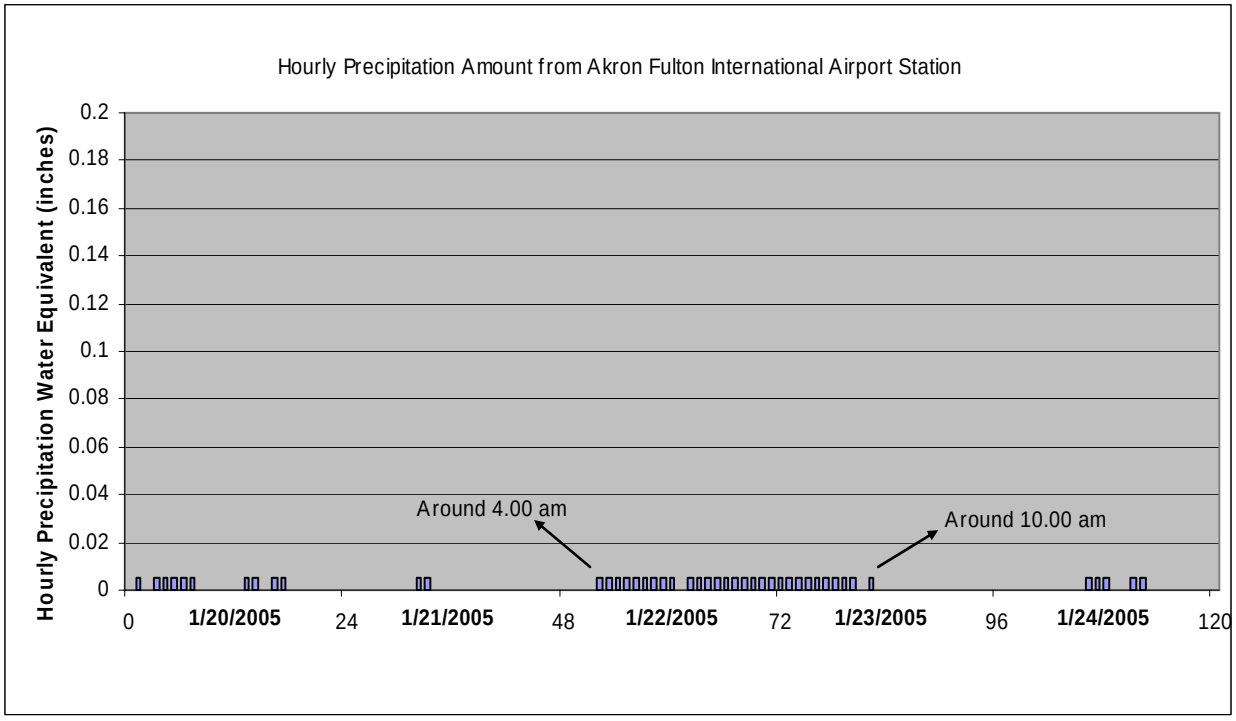

Figure 79: Hourly precipitation amount at station located in Akron.

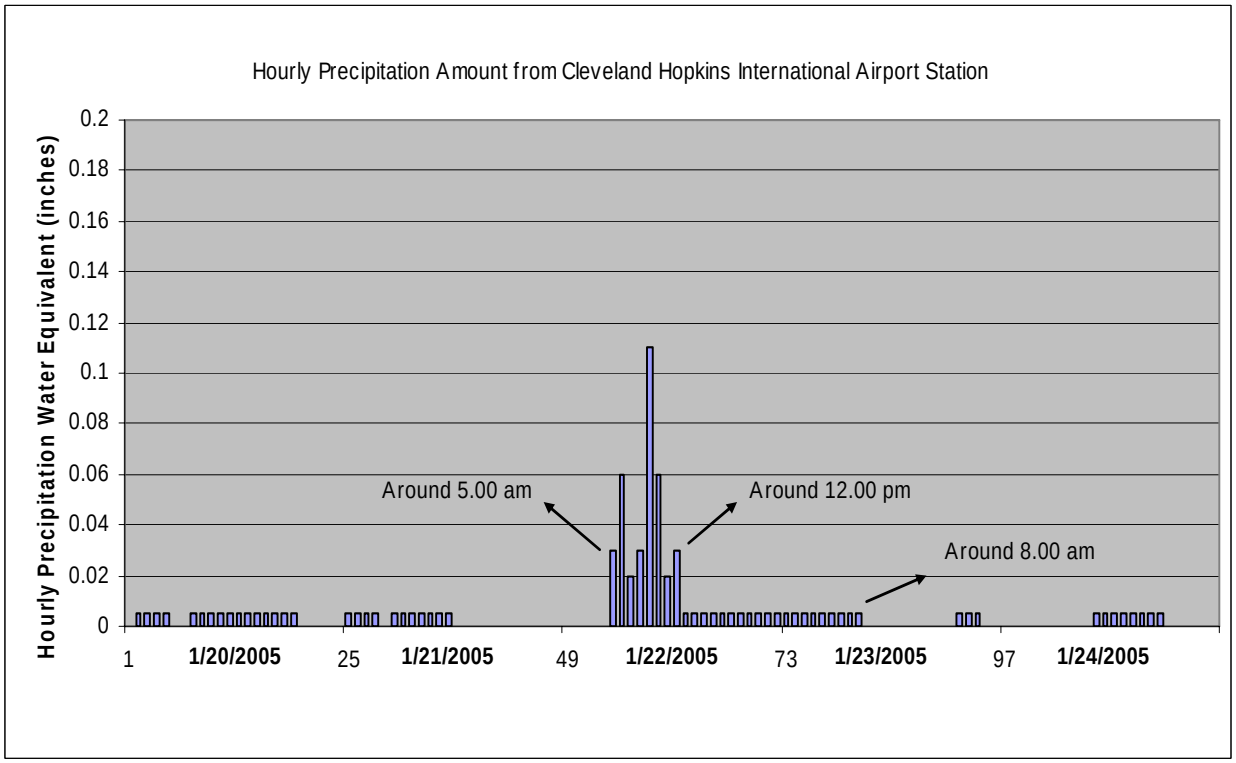

Figure 80: Hourly precipitation amount at station located in Cleveland.

8.4 Pictures from I-76 Westbound on January 22, 2005 until 11.30 am

Figure 81, Figure 82, Figure 83, Figure 84 and Figure 85 show the pictures taken on I-76 on January 22, 2005 before 11.30am. It can be seen that most of the road was covered with snow. Wheel tracks were visible in the driving lane.

Figure 81: Picture documenting typical road condition on the I-76 westbound in the morning of January 22, 2005. The road is covered with snow.

Figure 82: Picture documenting typical road condition on the exit ramp in the morning of January 22, 2005. The road is covered with snow.

Figure 83: Picture documenting typical road condition on the highway in the morning of January 22, 2005. The road is covered with snow.

Figure 84: Picture documenting typical road condition on the I-76 westbound in the morning of January 22, 2005. The road is covered with snow.

Figure 85: Picture documenting typical road condition in the morning at the rest area on I-76 where the survey was conducted on January 22, 2005. The road is covered with snow.

8.5 Pictures from I-76 Westbound on January 22, 2005 after 11.30 am

Figure 86, Figure 87, Figure 88, Figure 89 and Figure 90 show the pictures taken on January 22 on I-76. Figure 91 shows that the amount of snowfall on January 22, 2005 at the rest area on I-76 Westbound (greater than 3" (7.5 cm)).

Figure 86: Picture documenting typical road condition at the rest area on I-76 where the survey was conducted on January 22, 2005. The road is fairly clear with slight slush covered.

Figure 87: Picture documenting typical road condition on the I-76 westbound after 11.30 am on January 22, 2005. The road is fairly clear.

Figure 88: picture documenting typical road condition on the I-76 westbound after 11.30 am on January 22, 2005. The road is clear.

Figure 89: Picture documenting typical road condition on the free way entrance ramp near I-76 westbound after 11.30 am on January 22, 2005.

Figure 90: Picture documenting typical road condition on the I-76 westbound after 11.30 am on January 22, 2005. The road is clear.

Figure 91: Picture showing more than 3" (7.5 cm) of snowfall at the rest area on January 22, 2005.

9. RESULTS FOR THE SURVEY ON I-76

The results of the survey are given in this section. For each question, the number of respondents who answered is given for each day along with their percentage. A column chart is drawn to graphically show the results and compare both days.

Question 1

The first question the respondents were asked was at what time they arrived to the rest area. Before 11.30am on 22 January, 1 person arrived at dawn and 18 people arrived at daylight. After 11.30am, 18 people were surveyed during daylight, 1 person during dusk and 4 people at night. Table 48 shows the number of people surveyed during different periods.

Table 47 . Number of people surveyed at different periods.

		# Respondents	
Date		**12/22/2004**	**12/23/2004**
Period of Time	**Day light**	9	40
	Dark/Night time	31	0
	Dawn	0	0
	Dusk	12	0

Table 48 . Number of people surveyed at different periods.

		# Respondents	
Date: 01/22/2005		**Until 11.30 am**	**After 11.30 am**
Period of Time	**Day light**	18	18
	Dark/Night time	0	4
	Dawn	1	0
	Dusk	0	1

Table 49 . Number of car and truck drivers surveyed at different periods.

		# Respondents			
Date: 01/22/2005		**Until 11.30 am**		**After 11.30 am**	
Vehicle Type		**Cars**	**Trucks**	**Cars**	**Trucks**
Period of Time	**Day light**	10	8	13	5
	Dark/Night time	0	0	1	3
	Dawn	1	0	0	0
	Dusk	0	0	1	0

Question 2

Question 2 asked the gender of the respondent. Table 50 shows the number of respondents and percentages of both male and female on both days. Figure 92 shows their percentages graphically. Table 51 shows the number of respondents and percentages of both male and female car and truck drivers on both days. Figure 93 shows their percentages graphically. It can be observed that on both of the days the truck drivers were all male.

Table 50 . Male and female respondents for both periods.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
Gender	Male	18	94.74%	20	86.96%
	Female	1	5.26%	3	13.04%

Table 51 . Number and percentage of car and truck drivers according to gender of the respondents.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
Gender	Male	10	90.91%	8	100.00%	12	80.00%	8	100.00%
	Female	1	9.09%	0	0.00%	3	20.00%	0	0.00%

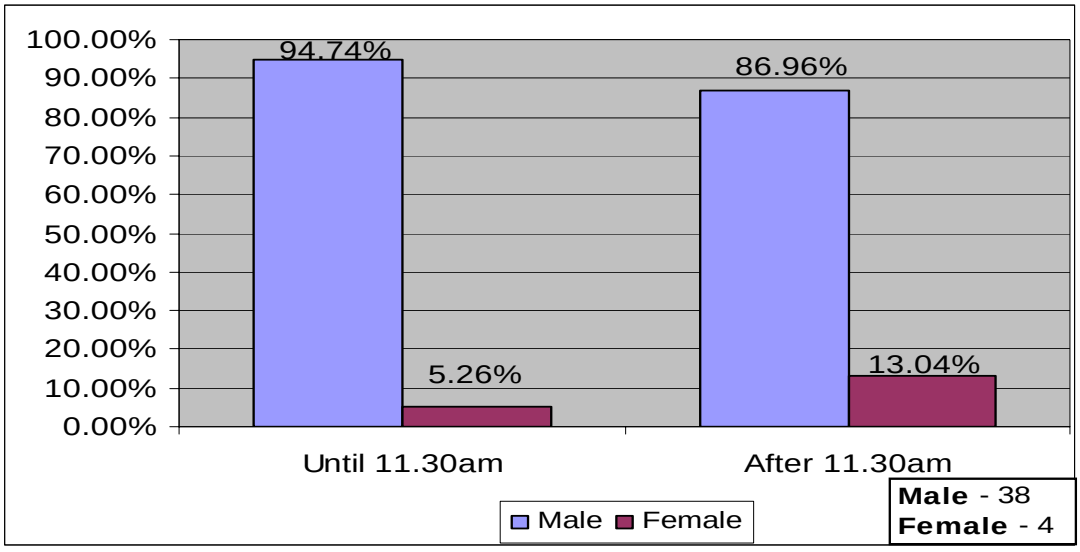

Figure 92: Response percentage of male and female.

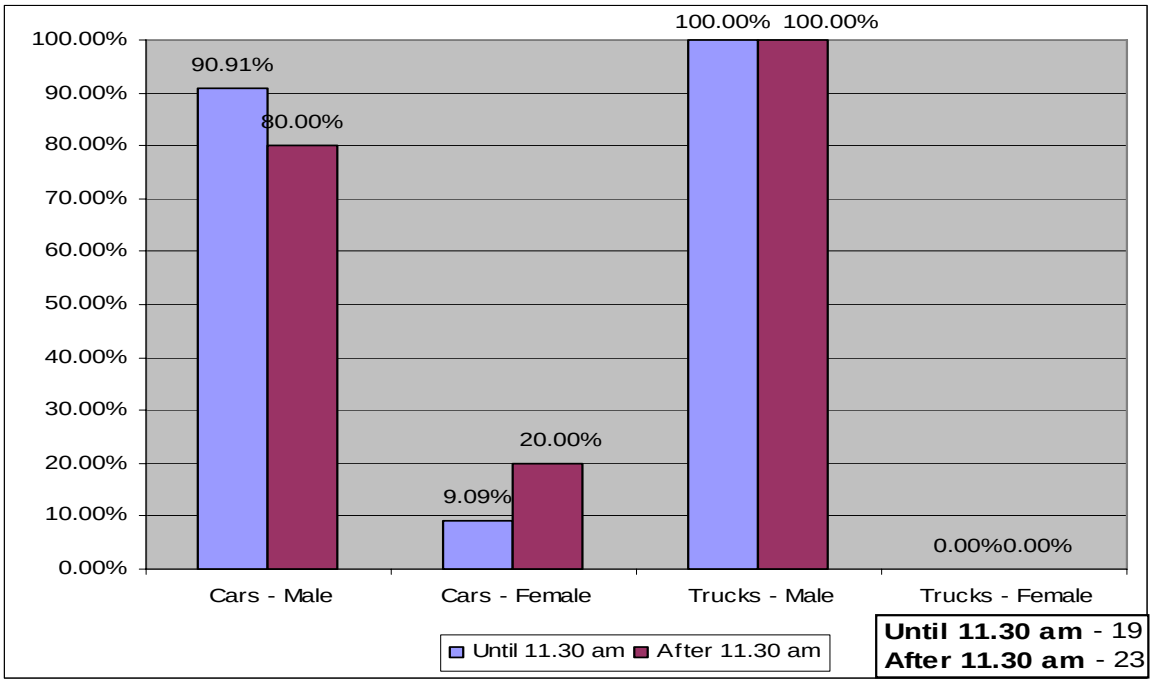

Figure 93: Response percentage of male and female car and truck drivers.

Question 3

The number of years of experience the driver had was asked in the third question. It was found that the average number of years is 27 for the survey conducted before 11.30 am and 26 years for the one conducted after 11.30 am. The minimum, maximum, mode, median, and standard deviation are given in Table 52. Figure 94 is a frequency graph of the number of drivers and their related experience. Grouping drivers by decades of experience that arrived before 11.30am, the largest group drivers surveyed had driving experience between 30 and 40 years, while those who arrived after 11.30am the largest group had 20 to 30 years driving experience.
It was found that the average driving experience is 34 years for car drivers and 17 years for truck drivers for the survey conducted until 11.30am and 26 years for car and truck drivers for those who arrived after 11.30am. The minimum, maximum, mode, median, and standard deviation for both car and truck drivers in both periods is given in Table 53. Figure 95 and Figure 96 are frequency graphs of the number of drivers and their related driving experience for car and truck drivers.

Table 52. Statistics of how many years the driver was driving.

		# Respondents	
Date: 01/22/2005		Until 11.30am	After 11.30am
How many years have you been driving?	Minimum	4	2
	Maximum	60	48
	Average	27.00	26.22
	Mode	35	27
	Median	21	26
	Standard Deviation	17.22	11.90

Table 53 . Statistics of how many years the driver was driving (car and truck drivers separate).

Date: 01/22/2005		Until 11.30 am		After 11.30 am	
Vehicle Type		Cars	Trucks	Cars	Trucks
How many years have you been driving?	Minimum	4	5	3	2
	Maximum	60	35	48	42
	Average	34.27	17.00	26.27	26.13
	Mode	35	18	27	40
	Median	35	18	27	25
	Standard Deviation	18.2	8.72	11.17	13.16

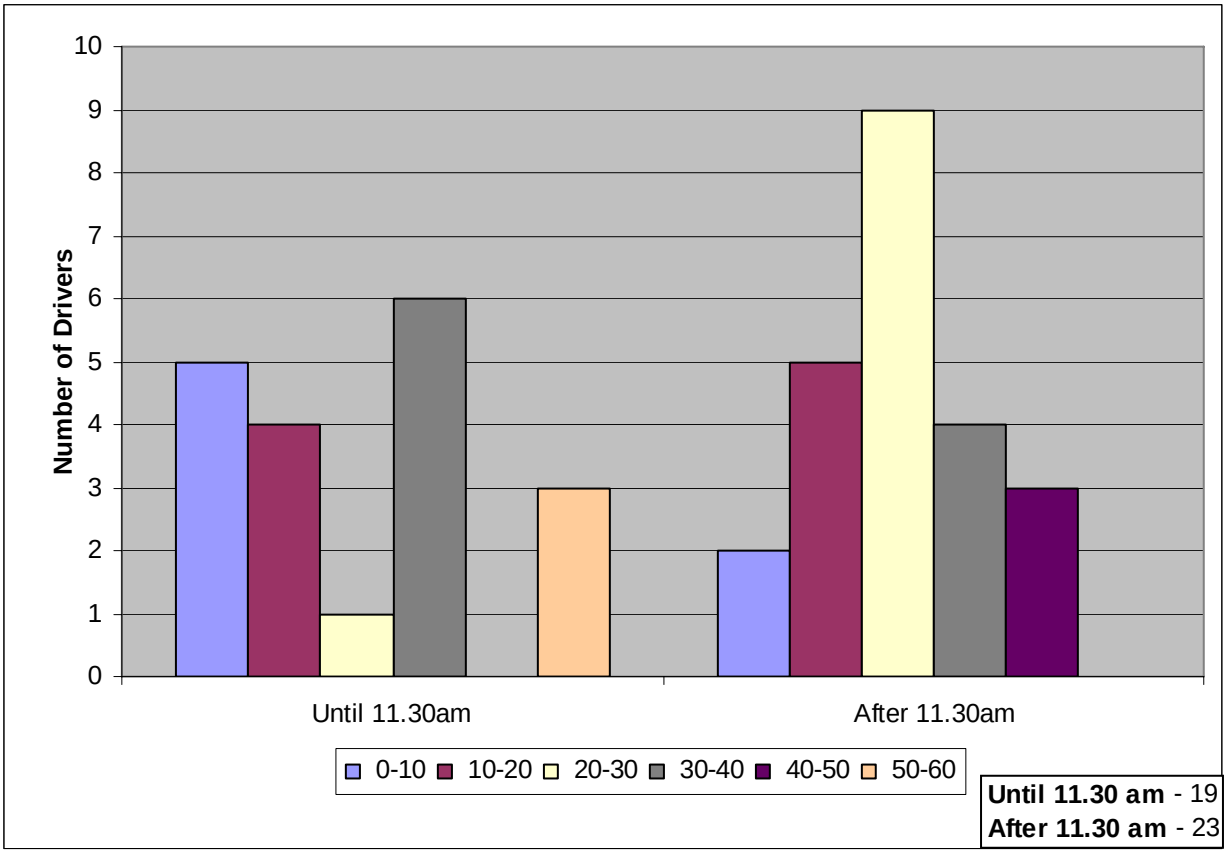

Figure 94: Graph showing relation between number of drivers and their experience.

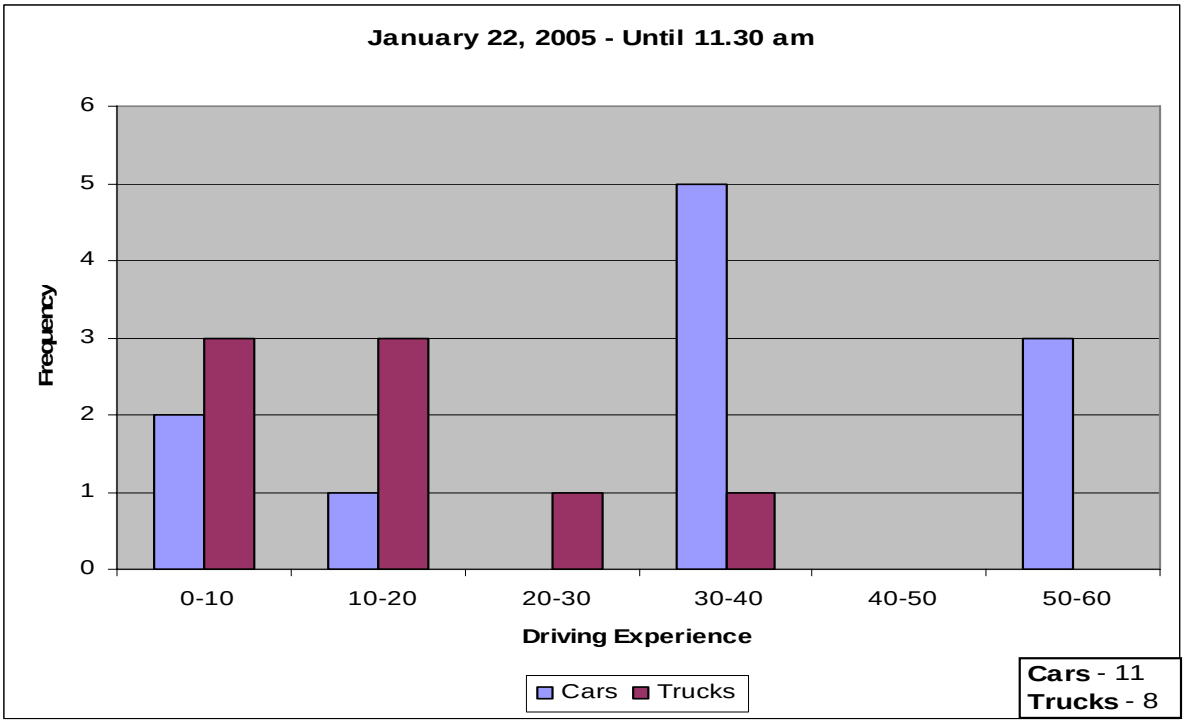

Figure 95: Graph showing relation between number of car and truck drivers and their driving experience who arrived before 11.30am.

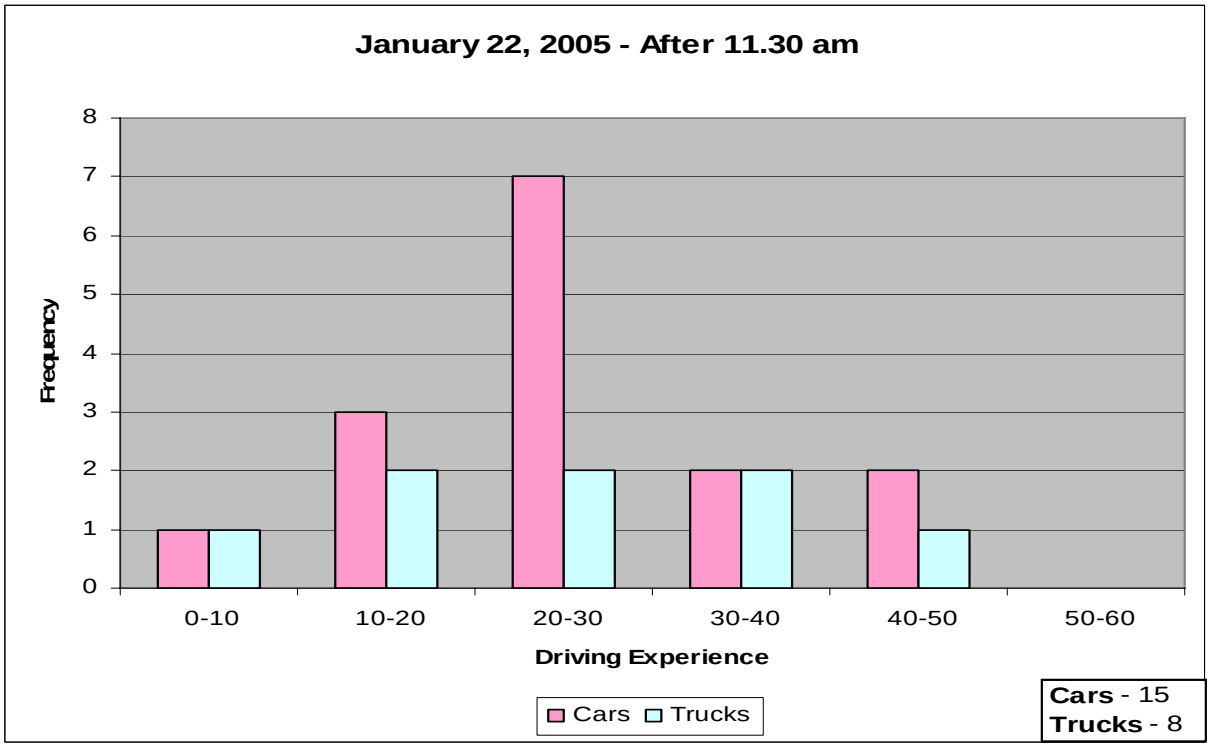

Figure 96: Graph showing relation between number of car and truck drivers and their driving experience who arrived after 11.30am.

Question 4

Question 4 asked how frequently the drivers drove that stretch of Westbound. The plurality of respondents answered that they drove a few times a month through that road. Only 16% drivers who arrived before 11.30am and 13% of drivers who arrived after 11.30am replied that they daily drove Westbound on this portion of I-76. Table 54 and Figure 97 signify the responses in tabular form and graphically respectively. Only 18% of car drivers, 12.5% of truck drivers who arrived before 11.30 am and 13% of car drivers and 12.5% of truck drivers who arrived after 11.30 am replied that they daily drove Westbound on this portion of I-76. Table 54 signifies the responses in a tabular form and Figure 98 and Figure 99 show them graphically for both the time periods on January 22.

Table 54 . Responses for how frequently drivers drove I-76 westbound.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
How frequently do you drive this stretch of the road?	Daily	3	15.79%	3	13.04%
	More than once per week	3	15.79%	5	21.74%
	About once per week	1	5.26%	2	8.70%
	A few times a month	8	42.11%	7	30.43%
	Rarely	4	21.05%	6	26.09%

Table 55 . Responses for how frequently car and truck drivers drove I-76 westbound.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How frequently do you drive this stretch of the road?	Daily	2	18.18%	1	12.50%	2	13.33%	1	12.50%
	More than once per week	0	0.00%	3	37.50%	4	26.67%	1	12.50%
	About once per week	1	9.09%	0	0.00%	1	6.67%	1	12.50%
	A few times a month	4	36.36%	4	50.00%	2	13.33%	5	62.50%
	Rarely	4	36.36%	0	0.00%	6	40.00%	0	0.00%

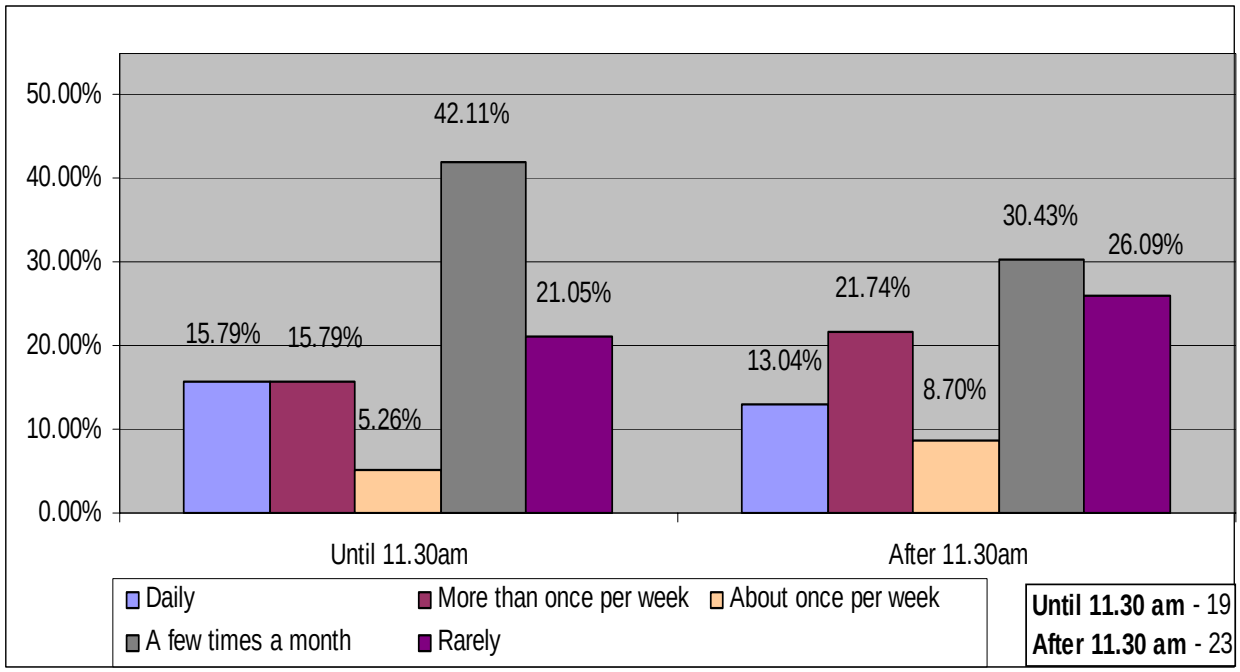

Figure 97: Frequency of people driving by I-76 westbound.

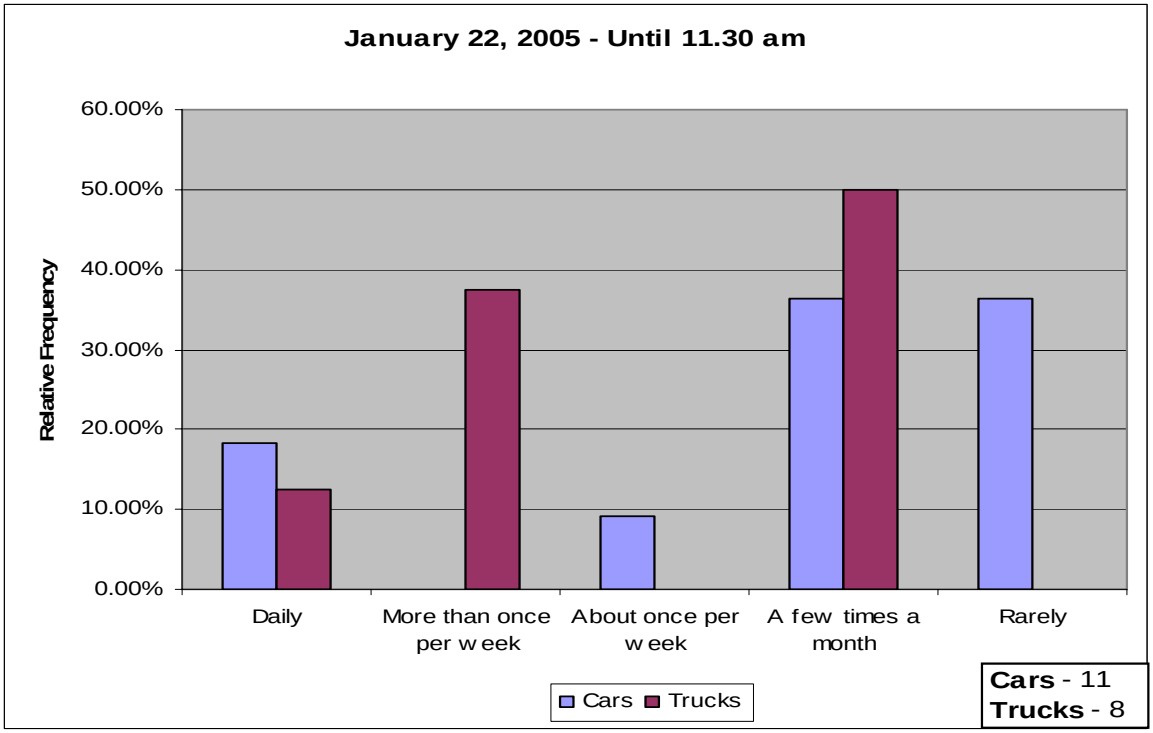

Figure 98: Relative frequency of people driving by I-76 westbound until 11.30am.

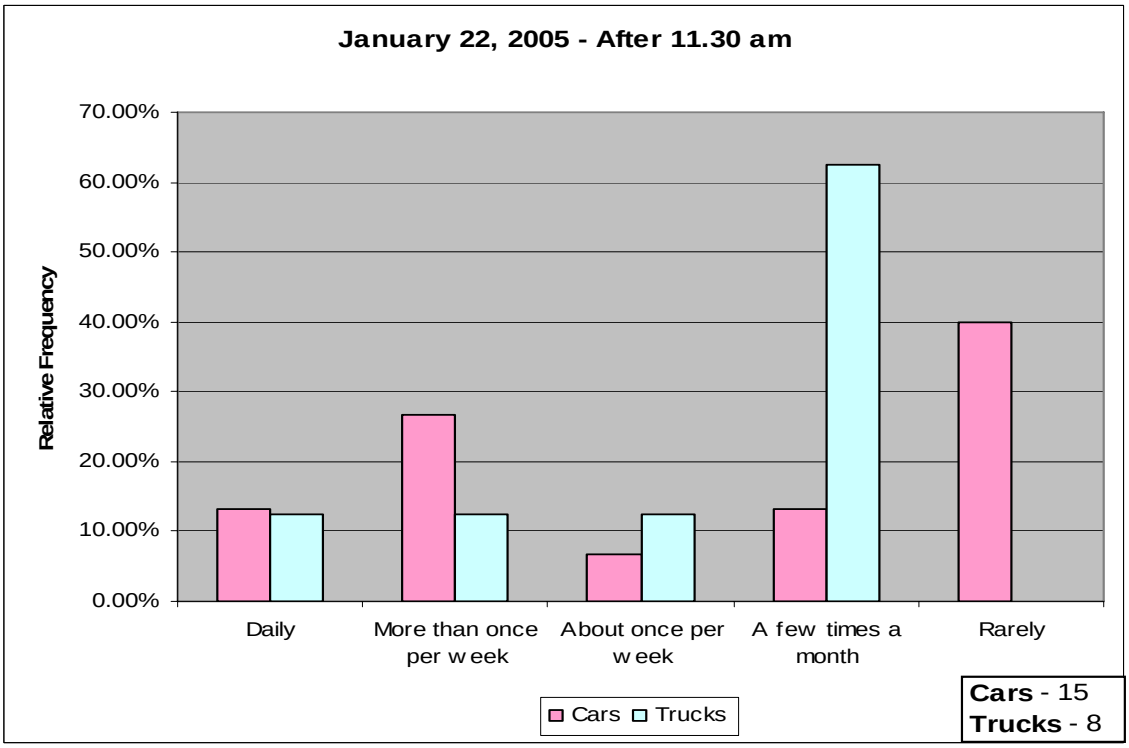

Figure 99: Frequency of people driving by I-76 westbound after 11.30am.

Question 5

The drivers were asked about the type of vehicle they were driving. Table 57 shows the number of drivers driving a particular type of vehicle. It can be seen that of all drivers who arrived before 11.30 am, 58% drove an automobile, van, SUV, or a pick-up truck while 42% drove large truck or a tractor-trailer. Of all the drivers who arrived after 11.30 am, 65% drove an automobile, van, SUV or pick-up truck while 35% drove large truck or a tractor-trailer. Figure 100 shows the percentage graphically.

Table 56: Number and Percentage of People Driving a Particular Type of Vehicle.

Date		12/22/2004		12/23/2004	
		# Respondents	Percentage	# Respondents	Percentage
What kind of vehicle are you driving?	Automobile/ Van	25	48.08%	19	47.50%
	SUV	6	11.54%	9	22.50%
	Pick-up	5	9.62%	2	5.00%
	Large truck	2	3.85%	0	0.00%
	Tractor-trailer	14	26.92%	10	25.00%
	Other (describe)	0	0.00%	0	0.00%

Table 57 shows the number of car and truck drivers driving a particular type of vehicle. Out of all the car drivers who arrived before 11.30 am, 46% drove an automobile/van, 27% drove SUV and 27% drove pick-up truck. 12.5% drove large truck and 87.5% drove tractor-trailer of all the truck drivers who arrived before 11.30 am. For the car drivers who arrived after 11.30 am 46% drove an automobile/van, 27% SUV and 27% drove pick-up truck while all the truck drivers drove a tractor-trailer. Figure 101 and Figure 102 shows the percentages graphically for drivers who arrived before 11.30 am and those who arrived after 11.30 am respectively.

Table 57 . Number and percentage of people driving a particular type of vehicle.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
What kind of vehicle are you driving?	Automobile/ Van	5	26.32%	7	30.43%
	SUV	3	15.79%	4	17.39%
	Pick-up	3	15.79%	4	17.39%
	Large truck	1	5.26%	0	0.00%
	Tractor-trailer	7	36.84%	8	34.78%
	Other (describe)	0	0.00%	0	0.00%

Table 58 . Number and percentage of car and truck drivers driving a particular type of vehicle.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
What kind of vehicle are you driving?	Automobile/ Van	5	45.45%	0	0.00%	7	46.67%	0	0.00%
	SUV	3	27.27%	0	0.00%	4	26.67%	0	0.00%
	Pick-up	3	27.27%	0	0.00%	4	26.67%	0	0.00%
	Large truck	0	0.00%	1	12.50%	0	0.00%	0	0.00%
	Tractor-trailer	0	0.00%	7	87.50%	0	0.00%	8	100.00%
	Other (describe)	0	0.00%	0	0.00%	0	0.00%	0	0.00%

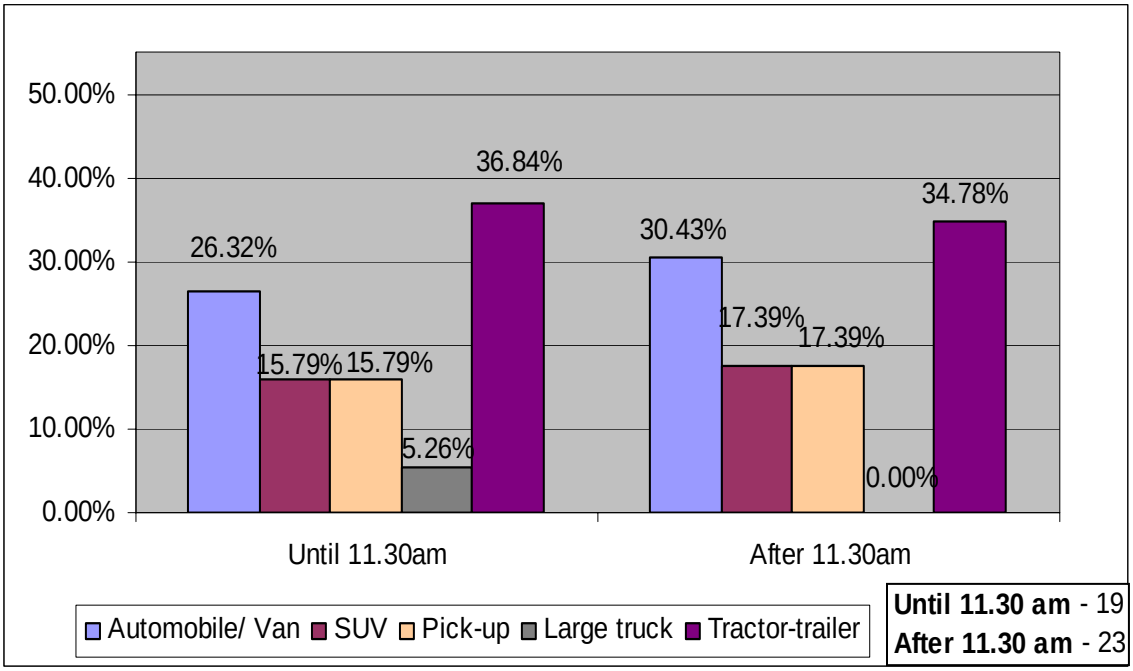

Figure 100: Percentage of drivers driving a particular type of vehicle.

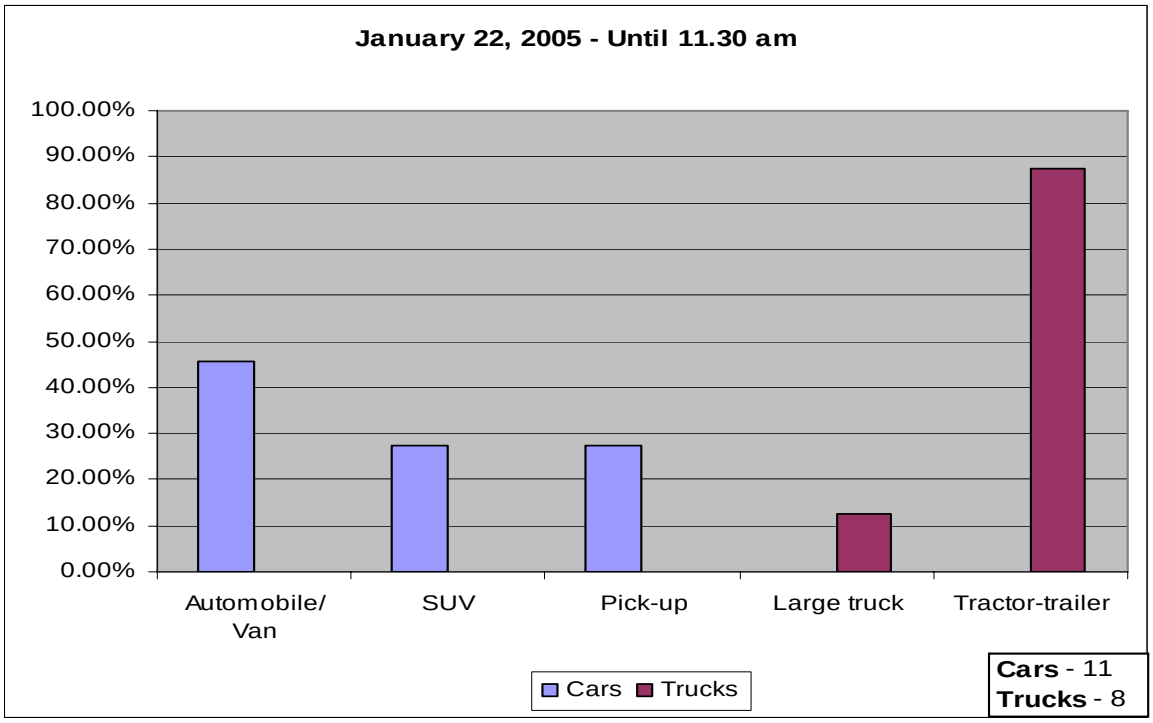

Figure 101: Percentage of car and truck drivers driving a particular type of vehicle who arrived before 11.30 am.

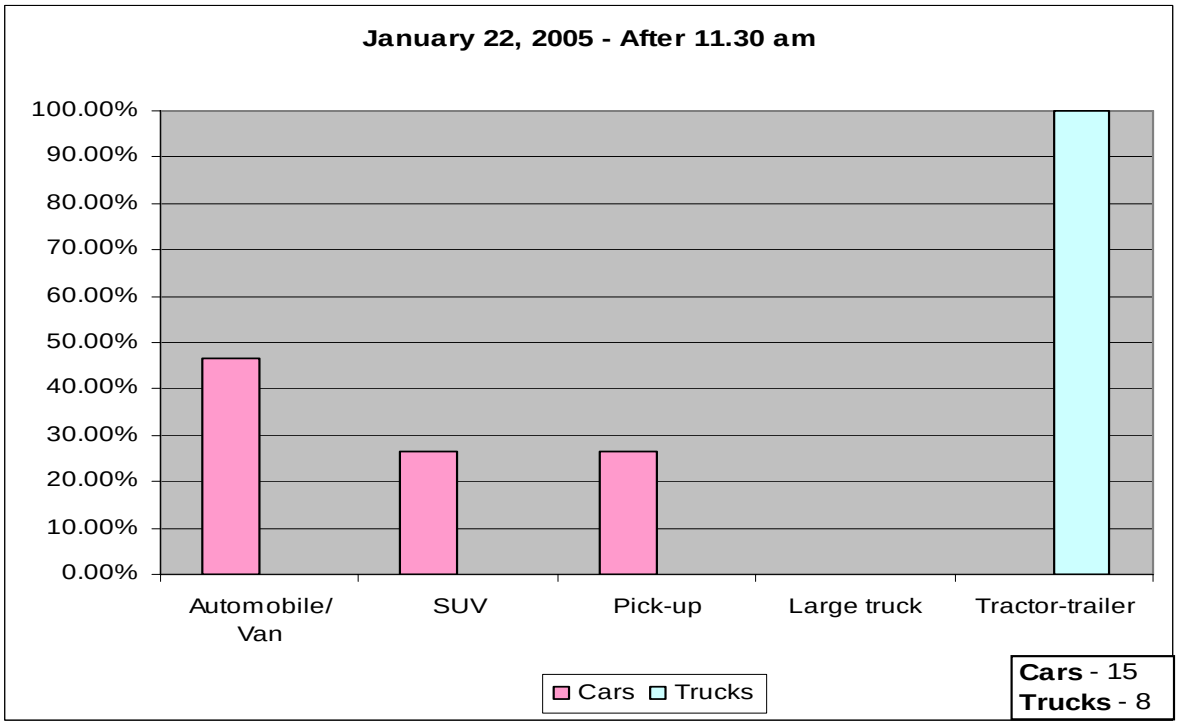

Figure 102: Percentage of car and truck drivers driving a particular type of vehicle who arrived after 11.30 am.

Question 6

Question 6 asked how many drivers were using two-wheel drive and how many were using four-wheel drive. Of those who arrived before 11.30 am, 37% used two-wheel drive while 37% used four-wheel drives. 74% of the drivers who arrived before 11.30 am used two-wheel drive and 13% used four-wheel drive. Drivers who were driving large trucks or tractor-trailers replied that they had neither two nor four-wheel drive, but were using the truck drive system available in the trucks. About 63% of the truck drivers who arrived before 11.30 am said they were using truck drive system while 38% said the same who arrived after 11.30 am. Table 59 show the responses for both type of drivers while Table 60 shows the responses for car and truck drivers separated. Figure 103, Figure 104 and Figure 105 represents the results graphically for both periods and both types of vehicles.

Table 59 . Driver responses for what type of drive system they were using.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
Did you drive using :	Two wheel drive (front/ rear)	7	36.84%	17	73.91%
	Four wheel drive	7	36.84%	3	13.04%
	Truck Drive System	5	26.32%	3	13.04%

Table 60 . Car and truck driver responses for what type of drive system they were using.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
Did you drive using :	Two wheel drive (front/ rear)	5	45.45%	2	25.00%	12	80.00%	5	62.50%
	Four wheel drive	6	54.55%	1	12.50%	3	20.00%	0	0.00%
	Truck Drive System	0	0.00%	5	62.50%	0	0.00%	3	37.50%

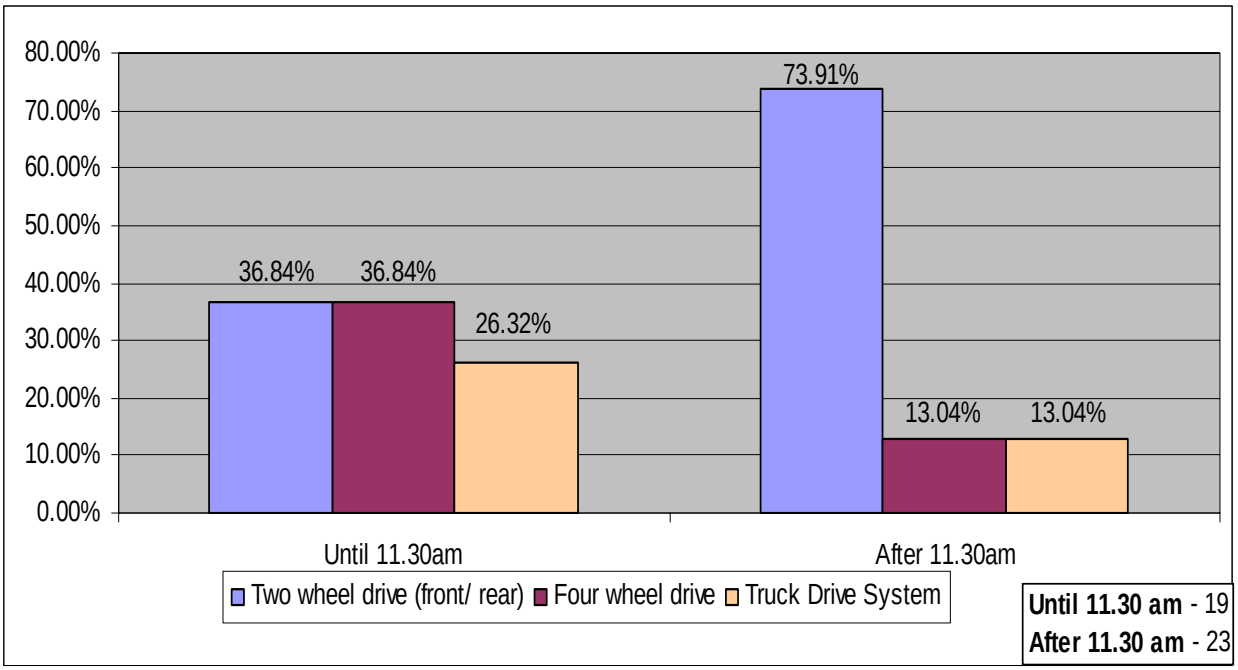

Figure 103: Graph showing the type of drive system used in percentages.

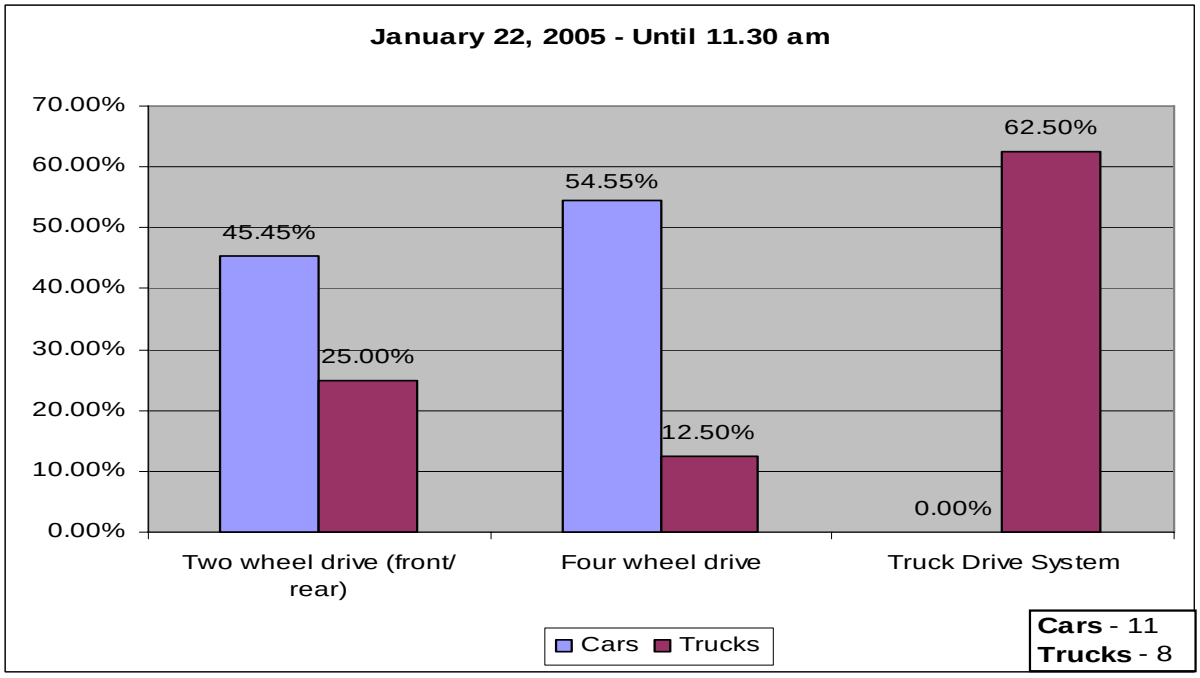

Figure 104: Graph showing the type of drive system used by car and truck drivers in percentages who arrived before 11.30 am.

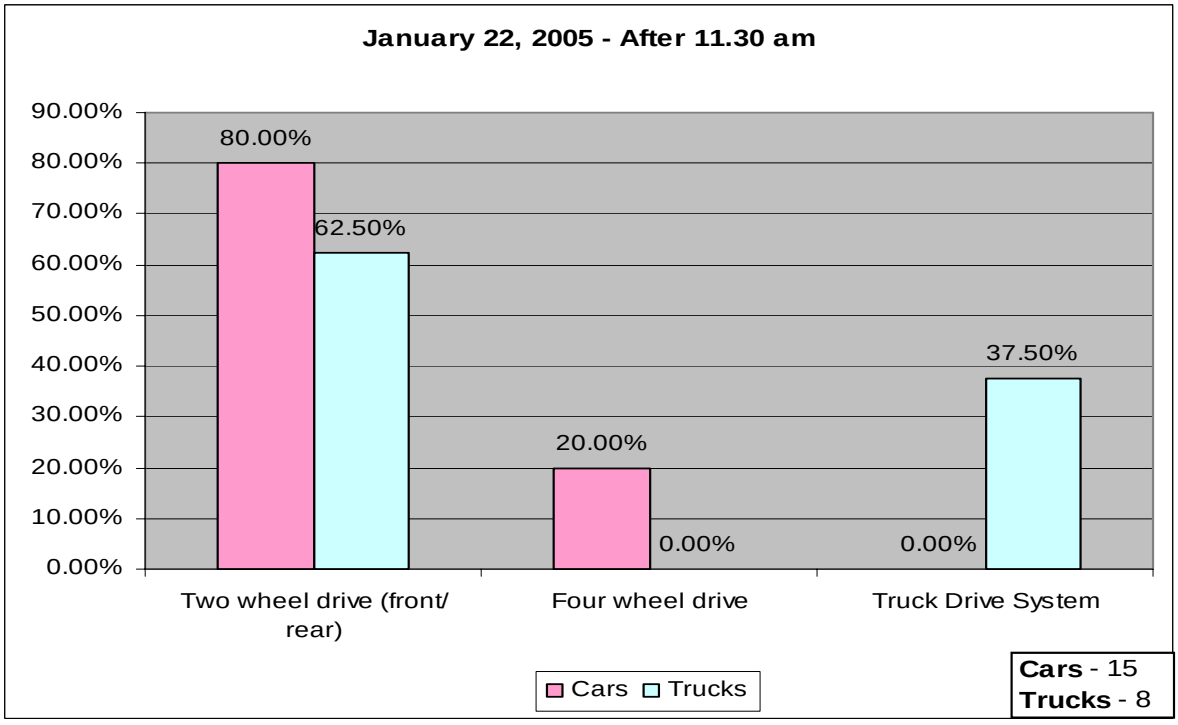

Figure 105: Graph showing the type of drive system used by car and truck drivers in percentages who arrived after 11.30 am.

Question 7

Question 7 asked how many drivers were using headlights while driving during the snowstorm. All of them irrespective of the period of time were using their headlights, which can be observed in Table 61 for all respondents and Table 62 for car and truck drivers separately and in Figure 106, Figure 107 and Figure 108 graphically for car and truck drivers who arrived before 11.30 am and those arriving after 11.30 am respectively.

Table 61 . Responses of drivers using headlights.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
Did you have your headlights on?	Yes	19	100.00%	23	100.00%
	No	0	0.00%	0	0.00%

Table 62 . Responses of car and truck drivers using headlights.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
Did you have your headlights on?	Yes	11	100.00%	8	100.00%	15	100.00%	8	100.00%
	No	0	0.00%	0	0.00%	0	0.00%	0	0.00%

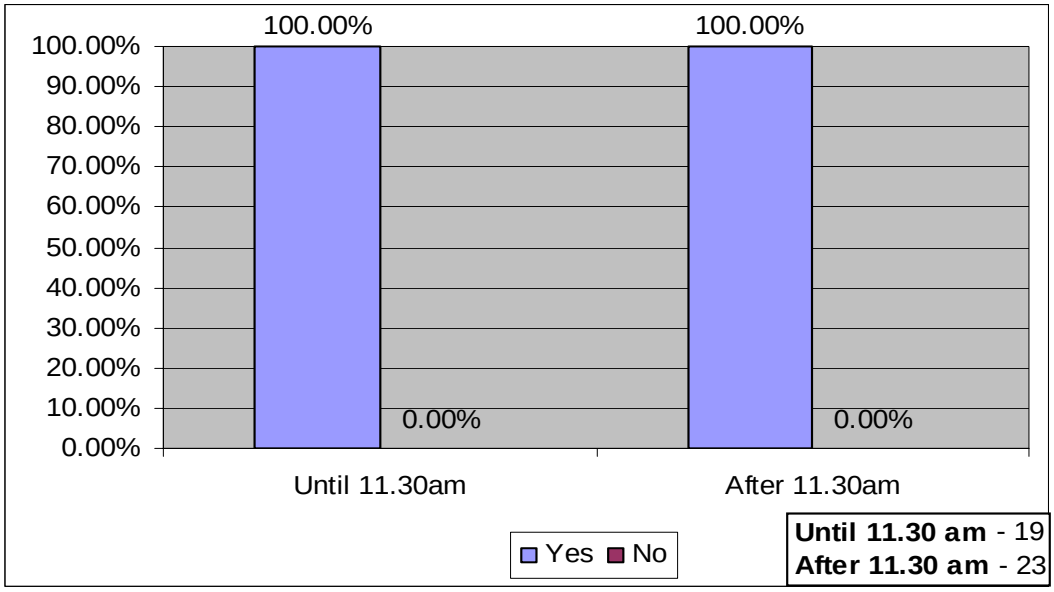

Figure 106: Graph representing the percentage of drivers using headlights.

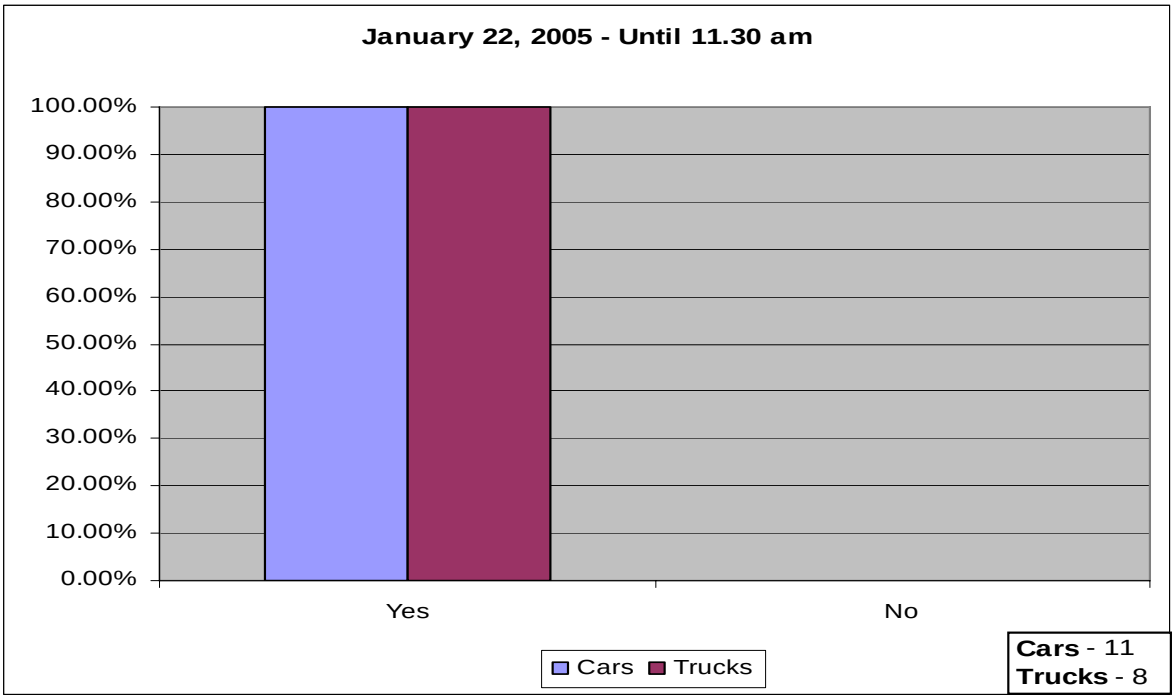

Figure 107: Graph representing the percentage of drivers using headlights who arrived before 11.30 am.

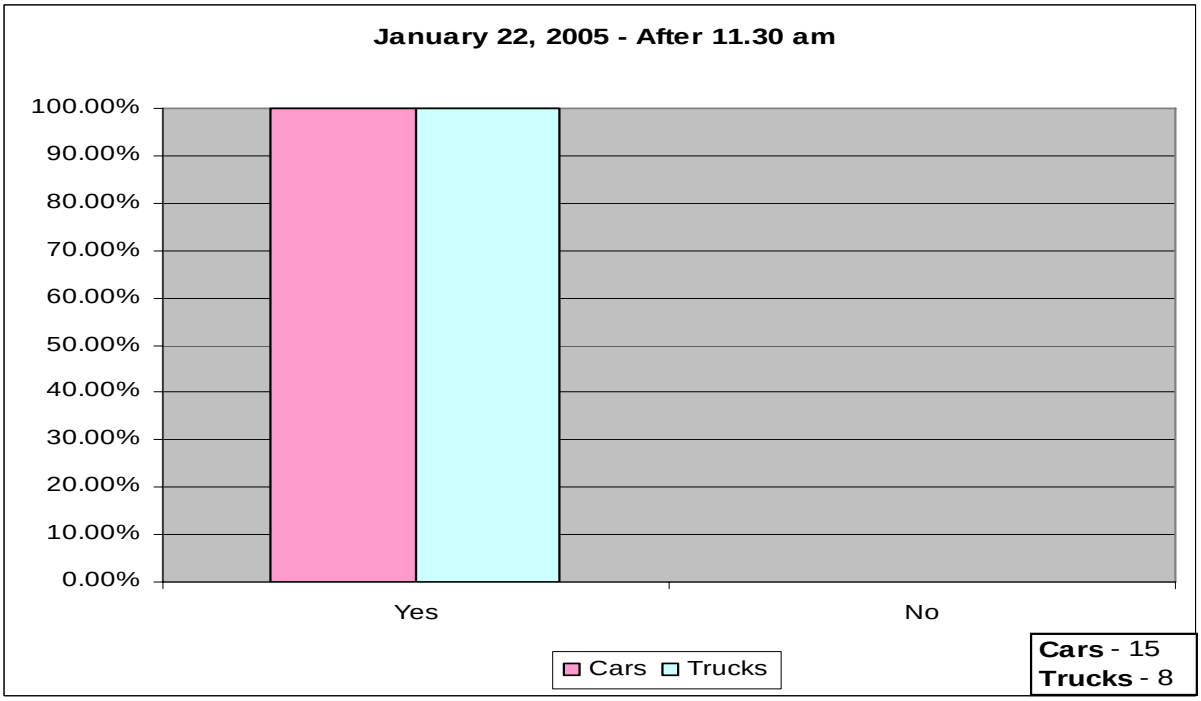

Figure 108: Graph representing the percentage of drivers using headlights who arrived after 11.30 am.

Question 8

The drivers were asked in which lane they were driving for the last few miles on I-76 Westbound. More than 90% of them replied that they drove in the right lane. Before 11.30 am 95% and after 11.30 am all of the drivers were using the right lane for most part of their travel which can be observed in Table 63. Figure 109 shows these responses graphically. From Table 64, it can be observed that all the car drivers were using the right lane mostly irrespective of the period of time while 87.5% of the truck drivers who arrived before 11.30 am and all the truck drivers who arrived after 11.30 am answered that they were using the right lane for most part during the drive for the last few miles. Figure 110 and Figure 111 shows the percentages of car and truck drivers using right and left lanes who arrived before 11.30 am and after 11.30 am respectively.

Table 63 . Responses of drivers about the lane they were driving for the last few miles.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
In which lane did you travel on this freeway for the last few miles or so?	Mostly in the right lane	18	94.74%	23	100.00%
	Mostly in the left or passing lane	1	5.26%	0	0.00%
	Both/ Not sure	0	0.00%	0	0.00%

Table 64 . Responses of car and truck drivers about the lane they were driving for the last few miles.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
In which lane did you travel on this freeway for the last few miles or so?	Mostly in the right lane	11	100.00%	7	87.50%	15	100.00%	8	100.00%
	Mostly in the left or passing lane	0	0.00%	1	12.50%	0	0.00%	0	0.00%
	Both/ Not sure	0	0.00%	0	0.00%	0	0.00%	0	0.00%

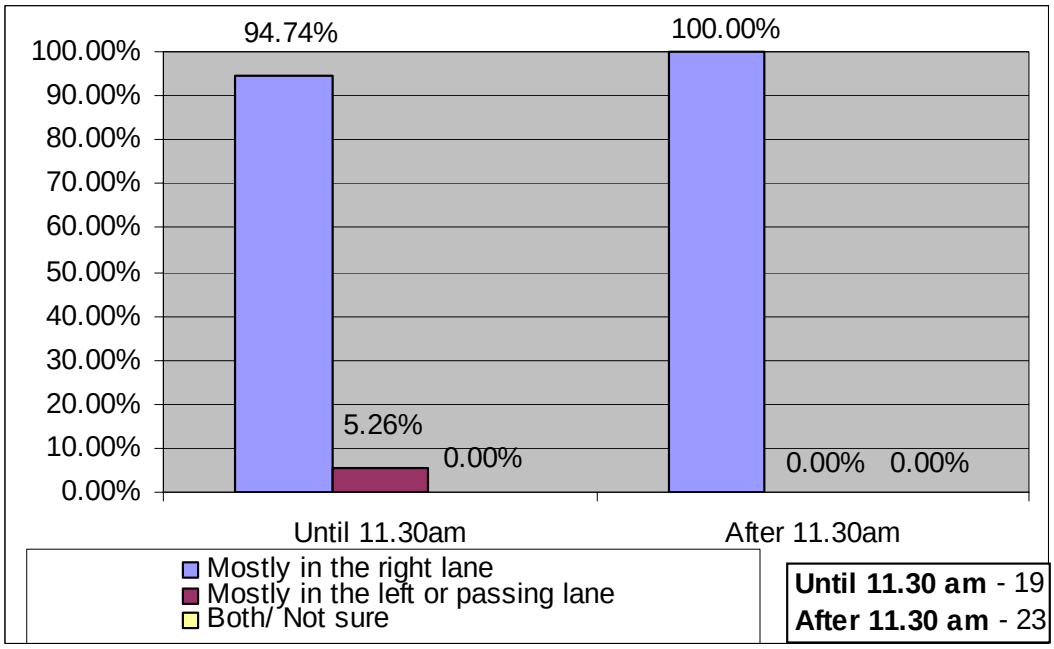

Figure 109: Graphical representation of the percentage of drivers driving in all lanes.

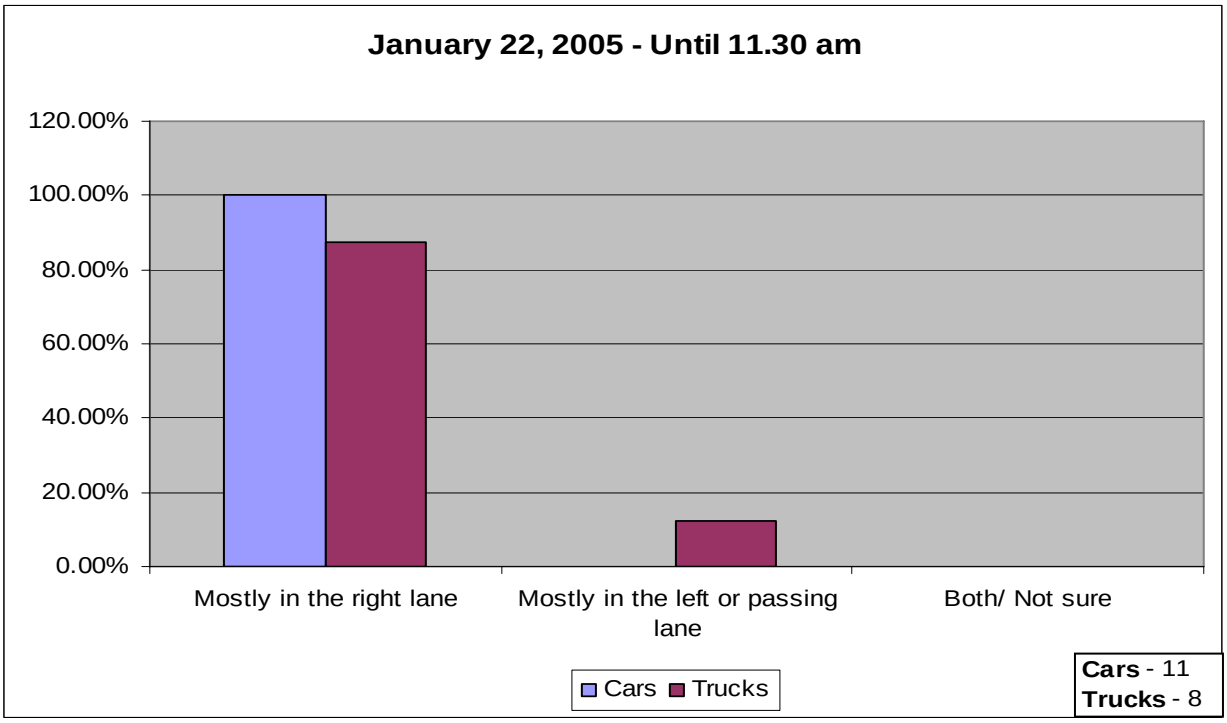

Figure 110: Graphical representation of the percentage of car and truck drivers driving in all lanes who arrived before 11.30 am.

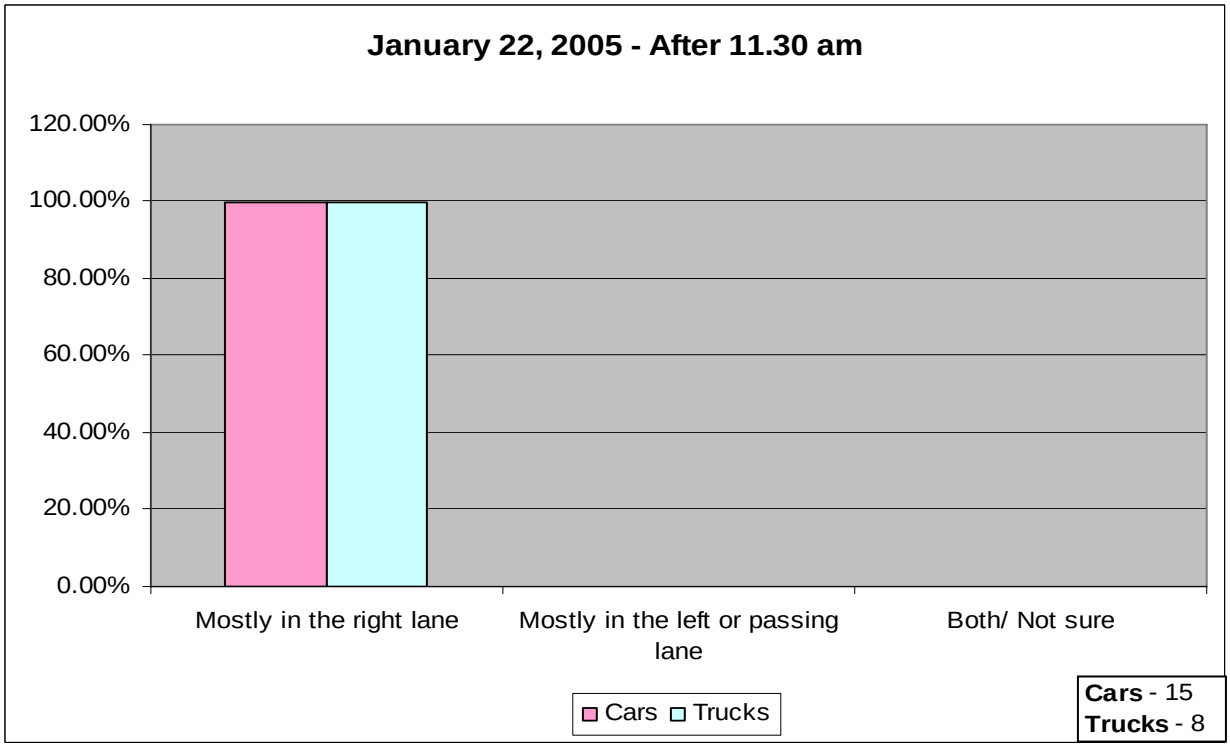

Figure 111: Graphical representation of the percentage of car and truck drivers driving in all lanes who arrived after 11.30 am.

Question 9

Question 9 asked about the speed at which the drivers were driving on I-76 Westbound during the snowstorm. The speed limit on that stretch of the road is 65 mph. Before 11.30 am about 32% of the drivers were driving either very slowly (more than 20 mph below the speed limit) or considerably below the speed limit (10-20 mph below). However after 11.30 am about 35% drivers drove about the speed limit and 48% drove slightly below the speed limit. The results can be seen in Table 65. Graphical representation can be observed in Figure 112. Table 66 shows the car and driver responses. Figure 113 and Figure 114 show the percentages graphically for drivers who arrived before 11.30 am and after 11.30 am.

Table 65 . Responses of drivers about the lane they were driving for the last few miles.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
At what speed did you drive most of the time during the last few miles or so?	About the speed limit	0	0.00%	8	34.78%
	Slightly below the speed limit (5-10 mph below	7	36.84%	11	47.83%
	Considerably below the speed limit (10-20 mph below)	6	31.58%	1	4.35%
	Very slowly (more than 20 mph below the speed limit)	6	31.58%	3	13.04%

Table 66 . Responses of car and truck drivers about the lane they were driving for the last few miles.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
At what speed did you drive most of the time during the last few miles or so?	About the speed limit	0	0.00%	0	0.00%	3	20.00%	5	62.50%
	Slightly below the speed limit (5-10 mph below	4	36.36%	3	37.50%	9	60.00%	2	25.00%
	Considerably below the speed limit (10-20 mph below)	5	45.45%	1	12.50%	0	0.00%	1	12.50%
	Very slowly (more than 20 mph below the speed limit)	2	18.18%	4	50.00%	3	20.00%	0	0.00%

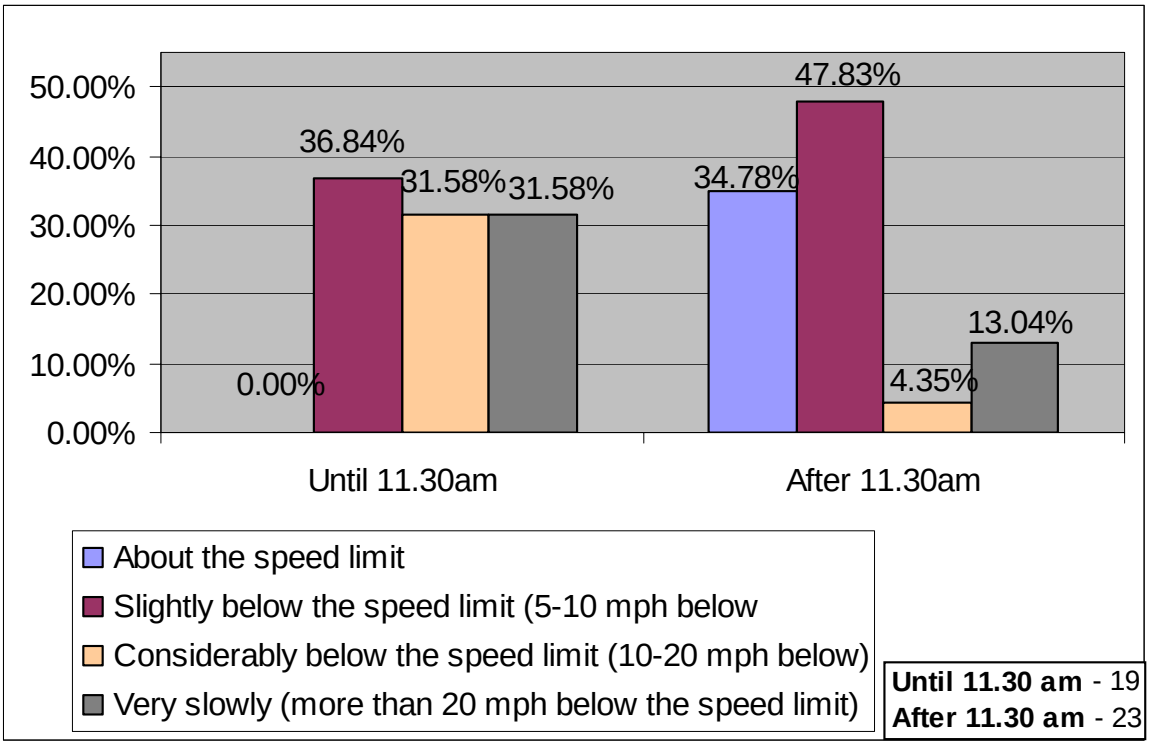

Figure 112: Graphical representation of driver speeds.

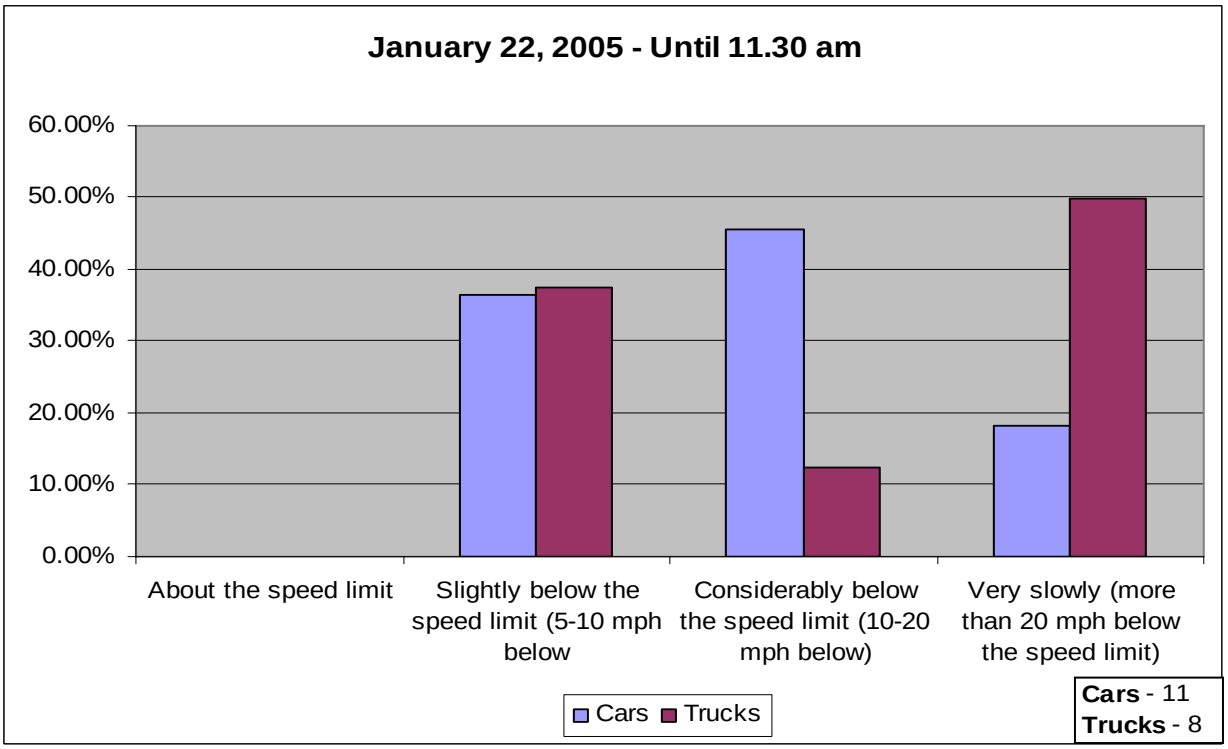

Figure 113: Graphical representation of car and truck driver speeds who arrived before 11.30 am.

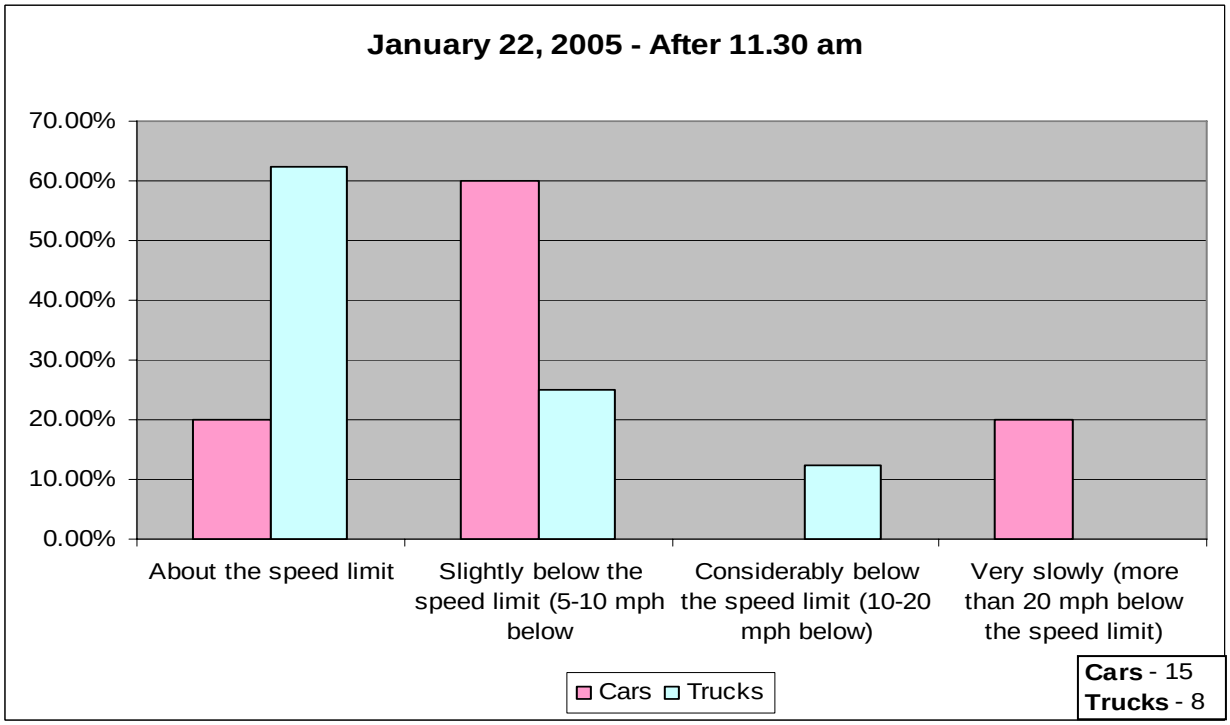

Figure 114: Graphical representation of car and truck driver speeds who arrived after 11.30 am.

Question 10

Following upon the previous question, the drivers were asked to rank the factors which they thought that reduced their driving speed. However, their response was different for both days. Most of the car drivers who were surveyed before and after 11.30 am and truck drivers who were surveyed before 11.30 am considered that the road surface condition mainly due to snow on road was the main factor that reduced their driving speed. But some of the truck drivers who were surveyed after 11.30 am thought the traffic around them was the main factor. Some of the truck drivers said the driving was fine owing to the fact that they did not reduce the driving speed. Table 67 gives the driver responses. Table 68 and Table 69 show the ranking of the factors by the drivers on both the periods. Table 70 represents the total responses of car and truck drivers for both the periods. Table 71 and Table 72 show the ranking of the factors for the car and truck drivers who arrived before 11.30 am, while Table 73 and Table 74 show the ranking of factors for car and truck drivers who arrived after 11.30 am.

Table 67 . Responses on why the drivers reduced their driving speed.

Date: 01/22/2005		Until 11.30am	After 11.30am
		# Respondents	# Respondents
What are the factors that reduced the driving speed?	The traffic around you (in front, in back)	5	7
	The visibility conditions due to falling snow, freezing rain, or other precipitation	4	6
	The visibility conditions due to blowing snow	11	4
	The visibility conditions due to fog	0	0
	The road surface conditions, mainly snow on road	12	12
	The road surface conditions, mainly icy and slippery road surface	9	10
	Activity near road such as construction or law enforcement	2	1
	Other (specify)	0	0
	None; driving was fine	0	8

Table 68 . Ranking of Factors that Reduced Driving Speed Until 11.30 am (Car and Truck Drivers together).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	2	3	0	0	0	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	3	1	0	0	0	0	0	0	0
The visibility conditions due to blowing snow	3	6	2	0	0	0	0	0	0
The visibility conditions due to fog	0	0	0	0	0	0	0	0	0
The road surface conditions, mainly snow on road	10	1	1	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	1	4	3	1	0	0	0	0	0
Activity near road such as construction or law enforcement	0	0	1	1	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 69 . Ranking of Factors that Reduced Driving Speed After 11.30 am (Car and Truck Drivers together).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	3	2	0	1	1	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	2	0	3	1	0	0	0	0	0
The visibility conditions due to blowing snow	0	1	2	1	0	0	0	0	0
The visibility conditions due to fog	0	0	0	0	0	0	0	0	0
The road surface conditions, mainly snow on road	8	4	0	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	2	5	3	0	0	0	0	0	0
Activity near road such as construction or law enforcement	0	1	0	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	8	0	0	0	0	0	0	0	0

Table 70 . Responses on why the car and truck drivers reduced their driving speed.

Date: 01/22/2005		Until 11.30 am		After 11.30 am	
Vehicle Type		Cars	Trucks	Cars	Trucks
		#	#	#	#
What are the factors that reduced the driving speed?	The traffic around you (in front, in back)	2	3	3	4
	The visibility conditions due to falling snow, freezing rain, or other precipitation	1	3	4	2
	The visibility conditions due to blowing snow	7	4	4	0
	The visibility conditions due to fog	0	0	0	0
	The road surface conditions, mainly snow on road	6	6	10	2
	The road surface conditions, mainly icy and slippery road surface	5	4	8	2
	Activity near road such as construction or law enforcement	1	1	0	1
	Other (specify)	0	0	0	0
	None; driving was fine	0	0	4	4

Table 71 . Ranking of factors that reduced driving speed of car drivers (until 11.30 am).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	1	1	0	0	0	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	1	0	0	0	0	0	0	0	0
The visibility conditions due to blowing snow	3	4	0	0	0	0	0	0	0
The visibility conditions due to fog	0	0	0	0	0	0	0	0	0
The road surface conditions, mainly snow on road	5	1	0	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	1	2	2	0	0	0	0	0	0
Activity near road such as construction or law enforcement	0	0	1	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 72 . Ranking of factors that reduced driving speed of truck drivers (until 11.30 am).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	1	2	0	0	0	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	2	1	0	0	0	0	0	0	0
The visibility conditions due to blowing snow	0	2	2	0	0	0	0	0	0
The visibility conditions due to fog	0	0	0	0	0	0	0	0	0
The road surface conditions, mainly snow on road	5	0	1	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	0	2	1	1	0	0	0	0	0
Activity near road such as construction or law enforcement	0	0	0	1	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	0	0	0	0	0	0	0	0	0

Table 73 . Ranking of factors that reduced driving speed of car drivers (after 11.30 am).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	0	2	0	0	1	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	2	0	1	1	0	0	0	0	0
The visibility conditions due to blowing snow	0	1	2	1	0	0	0	0	0
The visibility conditions due to fog	0	0	0	0	0	0	0	0	0
The road surface conditions, mainly snow on road	8	2	0	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	1	5	2	0	0	0	0	0	0
Activity near road such as construction or law enforcement	0	0	0	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	4	0	0	0	0	0	0	0	0

Table 74 . Ranking of factors that reduced driving speed of truck drivers (after 11.30 am).

Factors	Rank								
	1	2	3	4	5	6	7	8	9
The traffic around you (in front, in back)	3	0	0	1	0	0	0	0	0
The visibility conditions due to falling snow, freezing rain, or other precipitation	0	0	2	0	0	0	0	0	0
The visibility conditions due to blowing snow	0	0	0	0	0	0	0	0	0
The visibility conditions due to fog	0	0	0	0	0	0	0	0	0
The road surface conditions, mainly snow on road	0	2	0	0	0	0	0	0	0
The road surface conditions, mainly icy and slippery road surface	1	0	1	0	0	0	0	0	0
Activity near road such as construction or law enforcement	0	1	0	0	0	0	0	0	0
Other (specify)	0	0	0	0	0	0	0	0	0
None; driving was fine	4	0	0	0	0	0	0	0	0

Question 11

The drivers were asked about the road surface condition for the last few miles in which they were driving. Almost 89% drivers who arrived before 11.30 am opined that the road surface was 60% or less clear from edgeline to edgeline. However when things started to improve after 11.30 am, about 48% said that the road surface was 60% or less clear from edgeline to edgeline. Table 75 and Figure 115 show these results for car and truck drivers together and Table 76, Figure 116 and Figure 117 show these results separated for car and truck drivers.

Table 75 . Number of responses and percentages on the road condition.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
How was the road surface condition for the last few miles or so?	100 % clear pavement from edgeline to edgeline	0	0.00%	2	8.70%
	90 % clear pavement from edgeline to edgeline	0	0.00%	4	17.39%
	80 % clear pavement from edgeline to edgeline	0	0.00%	2	8.70%
	70 % clear pavement from edgeline to edgeline	2	10.53%	4	17.39%
	60 % or less clear pavement from edgeline to edgeline	17	89.47%	11	47.83%

Table 76 . Number of responses and percentages on the road condition (car and truck drivers separate).

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How was the road surface condition for the last few miles or so?	100 % clear pavement from edgeline to edgeline	0	0.00%	0	0.00%	2	13.33%	0	0.00%
	90 % clear pavement from edgeline to edgeline	0	0.00%	0	0.00%	2	13.33%	2	25.00%
	80 % clear pavement from edgeline to edgeline	0	0.00%	0	0.00%	0	0.00%	2	25.00%
	70 % clear pavement from edgeline to edgeline	0	0.00%	2	25.00%	4	26.67%	0	0.00%
	60 % or less clear pavement from edgeline to edgeline	11	100.00%	6	75.00%	7	46.67%	4	50.00%

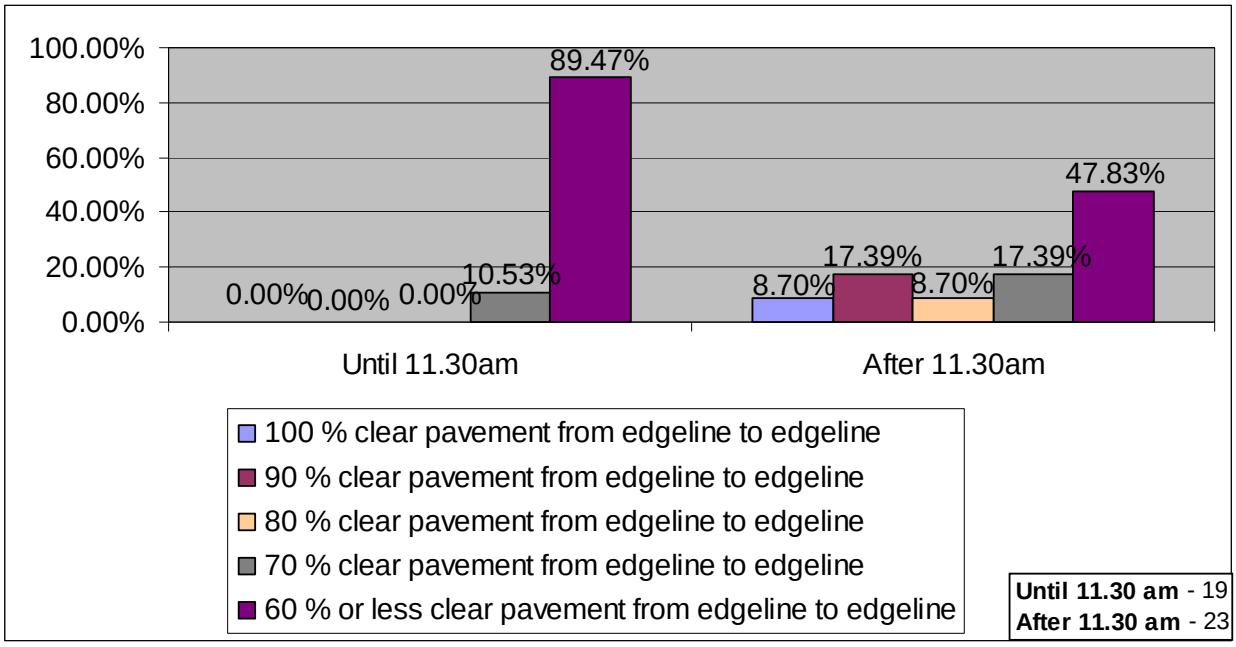

Figure 115: Response percentage for each factor about the road condition.

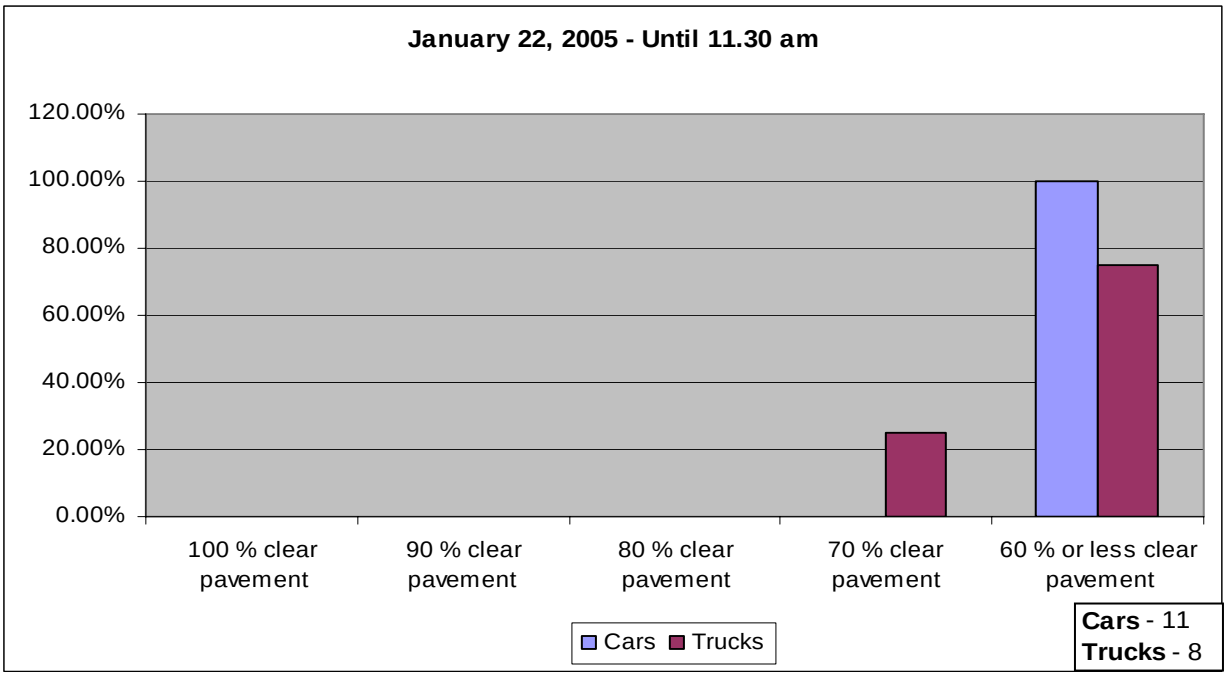

Figure 116: Response percentage for each factor about the road condition who arrived before 11.30 am (car and truck drivers separate).

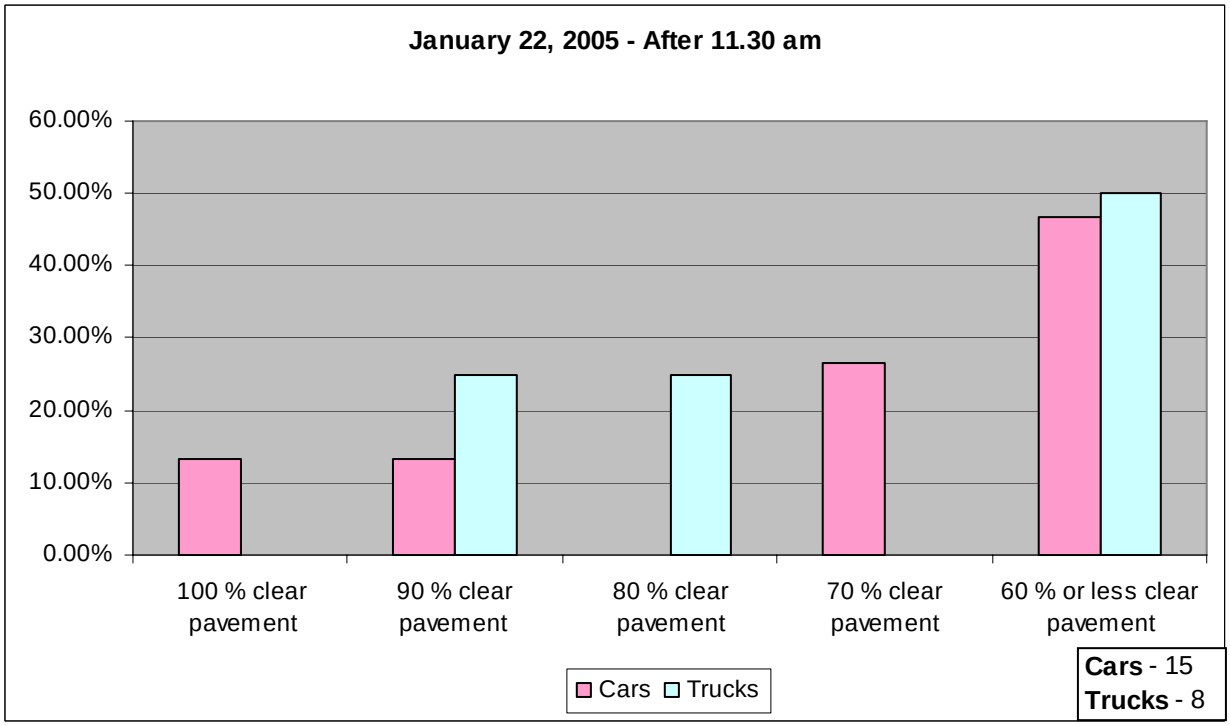

Figure 117: Response percentage for each factor about the road condition who arrived after 11.30 am (car and truck drivers separate).

Question 12

Question 12 asked about the conditions in the lane they drove for most part during the last few miles. Respondents checked all the options which they thought that prevailed in the lane they drove. Driver who arrived before 11.30 am answered that their lane was covered with snow, while most of the drivers arriving after 11.30 am thought that their lane was either covered with snow or/and snow covered in spots. After 11.30 am two persons driving car and two driving trucks opined that the road surface was clear without any snow on them. Table 77 shows the driver responses while Table 78 shows the car and truck driver responses separated.

Table 77 . Driver responses about the conditions in the lane they drove.

Date: 01/22/2005		Until 11.30am	After 11.30am
		# Respondents	# Respondents
Describe the current conditions in the lane you drove in the most for the last few miles or so.	Clear	0	4
	Snow covered	16	8
	Snow covered in spots	4	9
	Drifted snow	1	2
	Icy	0	2
	Icy in spots	2	4
	Slush covered	0	5
	Blocked	0	0

Table 78 . Car and truck driver responses about the conditions in the lane they drove.

Date: 01/22/2005		Until 11.30 am		After 11.30 am	
Vehicle Type		Cars	Trucks	Cars	Trucks
		#	#	#	#
Describe the current conditions in the lane you drove in the most for the last few miles or so.	Clear	0	0	2	2
	Snow covered	9	7	6	2
	Snow covered in spots	3	1	6	3
	Drifted snow	1	0	2	0
	Icy	0	0	2	0
	Icy in spots	1	1	4	0
	Slush covered	0	0	4	1
	Blocked	0	0	0	0

Question 13

The drivers were asked if there were wheel tracks on which they could drive, if the roads were covered with snow. About 79% of the drivers who arrived before 11.30 am replied there were wheel tracks in the right lane. Almost 35% of drivers who arrived after 11.30 am said that they were wheel tracks visible in both the lanes and about 39% replied that there were wheel tracks in the right lane only.
91% of the car drivers and 63% of the truck drivers who arrived before 11.30 am replied that there were tracks in the right lane only. After 11.30 am 47% of car drivers and 25% of truck drivers replied that there were wheel tracks in the right lane only. 33% of car drivers and 38% of truck drivers said that there were wheel tracks in both lanes. Table 79 gives the driver responses on visibility and graphically plotted as shown in Figure 118. Table 80 shows the car and drivers responses and they can be seen graphically in Figure 119 and Figure 120.

Table 79 . Responses on visibility of wheel tracks.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
If the road had snow cover, were there wheel tracks you could drive on?	No tracks - the road was covered with snow	1	5.26%	2	8.70%
	Wheel tracks in the right (driving) lane only	15	78.95%	9	39.13%
	Wheel tracks in the left (passing) lane only	1	5.26%	0	0.00%
	Wheel tracks in both lanes	2	10.53%	8	34.78%

Table 80 . Responses on visibility of wheel tracks.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
If the road had snow cover, were there wheel tracks you could drive on?	No tracks - the road was covered with snow	0	0.00%	1	12.50%	1	6.67%	1	12.50%
	Wheel tracks in the right (driving) lane only	10	90.91%	5	62.50%	7	46.67%	2	25.00%
	Wheel tracks in the left (passing) lane only	0	0.00%	1	12.50%	0	0.00%	0	0.00%
	Wheel tracks in both lanes	1	9.09%	1	12.50%	5	33.33%	3	37.50%

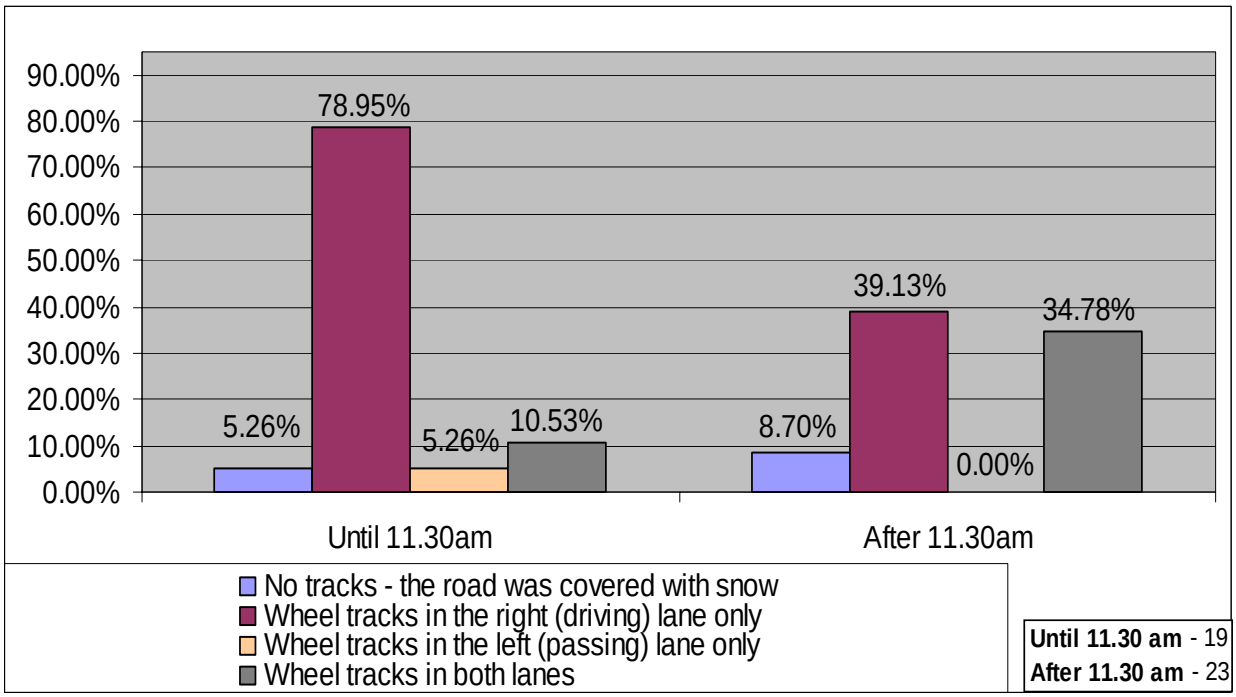

Figure 118: Percentage of wheel tracks visibility on the lanes.

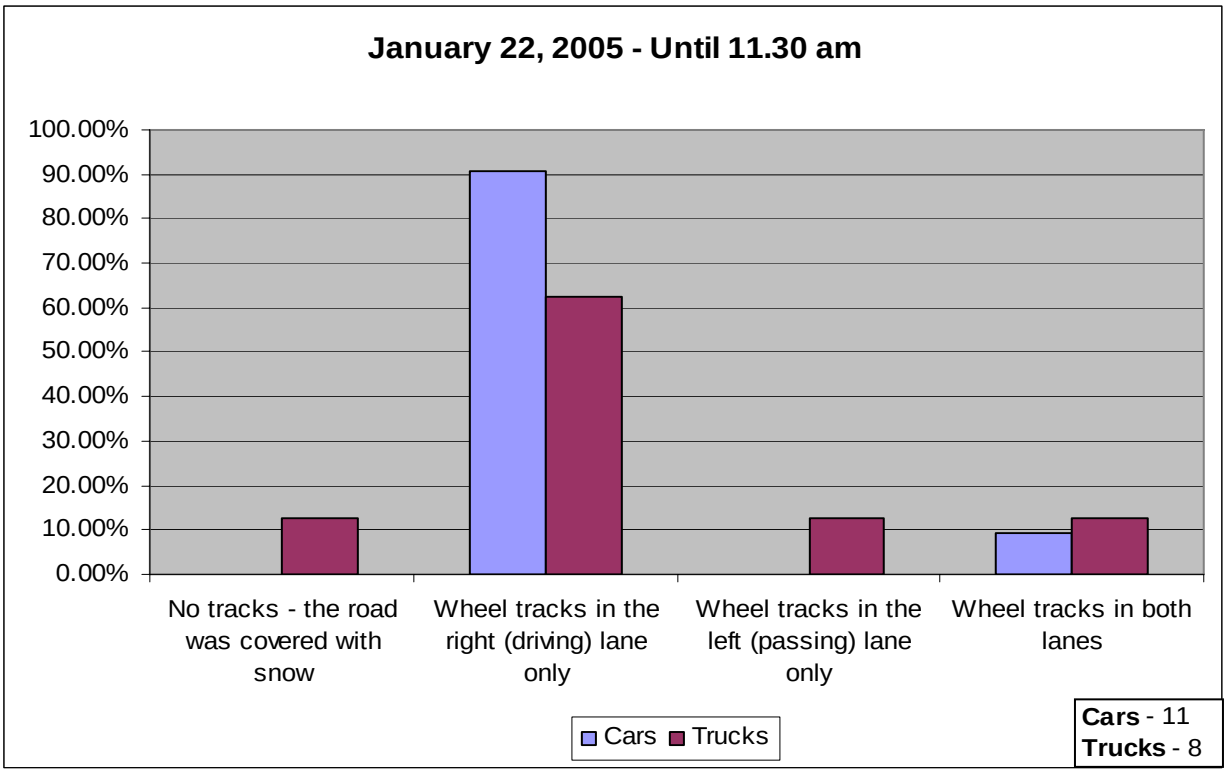

Figure 119: Percentage of wheel tracks visibility on the lanes (until 11.30 am).

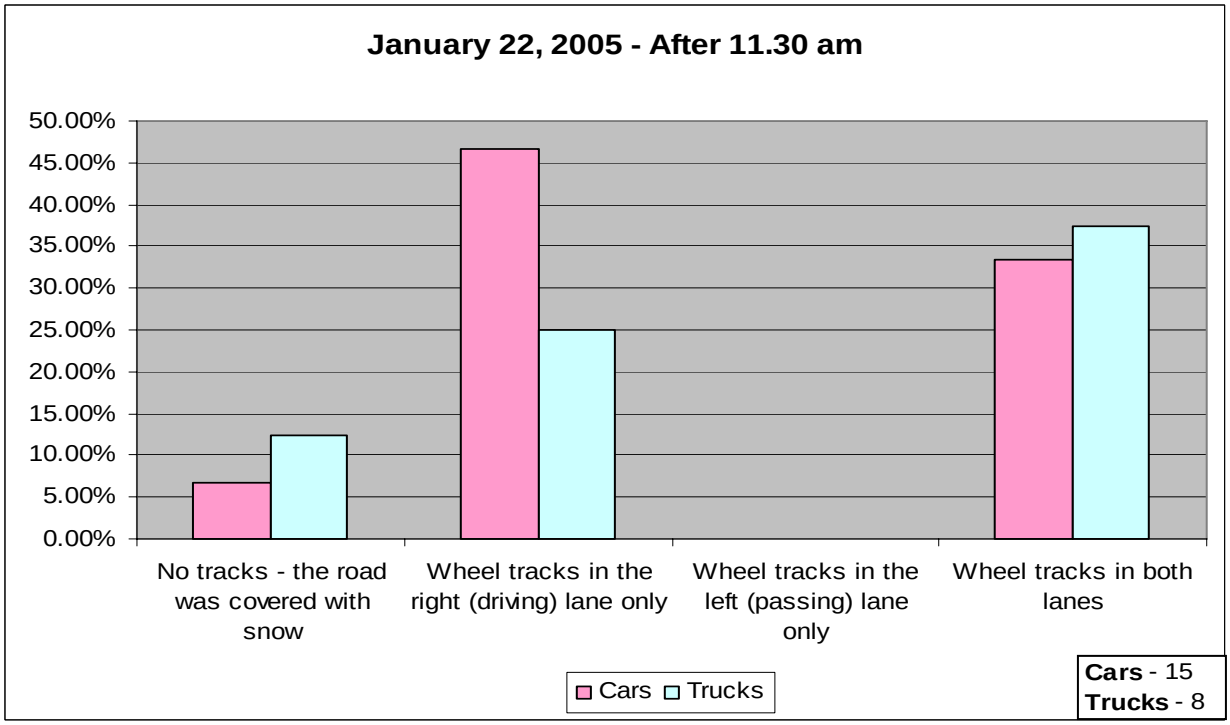

Figure 120: Percentage of wheel tracks visibility on the lanes (after 11.30 am).

Question 14

Drivers were asked to rate the clearing and treatment of the roads for the last few miles. Table 81 shows the responses and in Figure 121 they can be seen graphically. Table 82 shows the responses separated for car and truck drivers and in Figure 122 and Figure 123 they can be seen graphically for both the periods. Respondents who arrived before 11.30 am tended to rate the road treatment as fair or poor. After 11.30 am the most of the drivers rated the road clearing and treatment as good. A few responded that the treatment was very good or excellent considering the extreme conditions of the storm.

Table 81 . Responses on road clearing and treatment.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
How would you rate the clearing and treatment of the last few miles or so of this road during this storm?	Excellent	0	0.00%	2	8.70%
	Very Good	2	10.53%	1	4.35%
	Good	3	15.79%	13	56.52%
	Fair	5	26.32%	7	30.43%
	Poor	9	47.37%	0	0.00%

Table 82 . Responses of car and truck drivers on road clearing and treatment.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How would you rate the clearing and treatment of the last few miles or so of this road during this storm?	Excellent	0	0.00%	0	0.00%	2	13.33%	0	0.00%
	Very Good	1	9.09%	1	12.50%	0	0.00%	1	12.50%
	Good	2	18.18%	1	12.50%	9	60.00%	4	50.00%
	Fair	3	27.27%	2	25.00%	4	26.67%	3	37.50%
	Poor	5	45.45%	4	50.00%	0	0.00%	0	0.00%

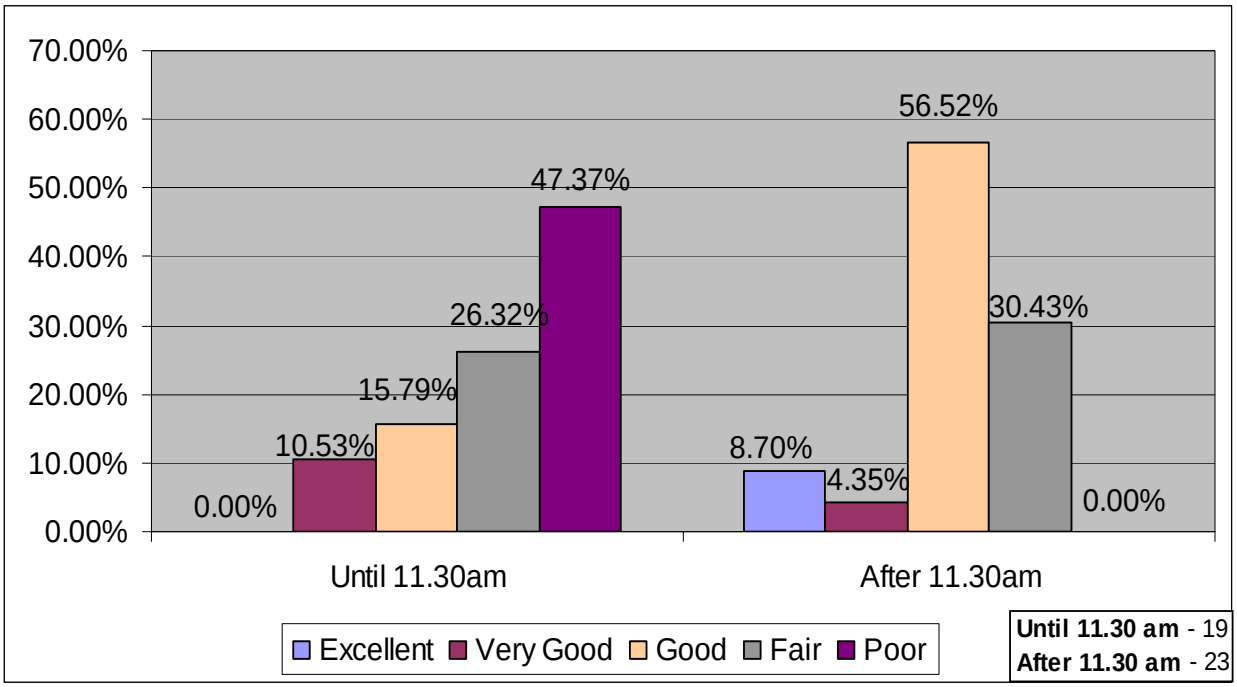

Figure 121: Rating of the road clearing and treatment.

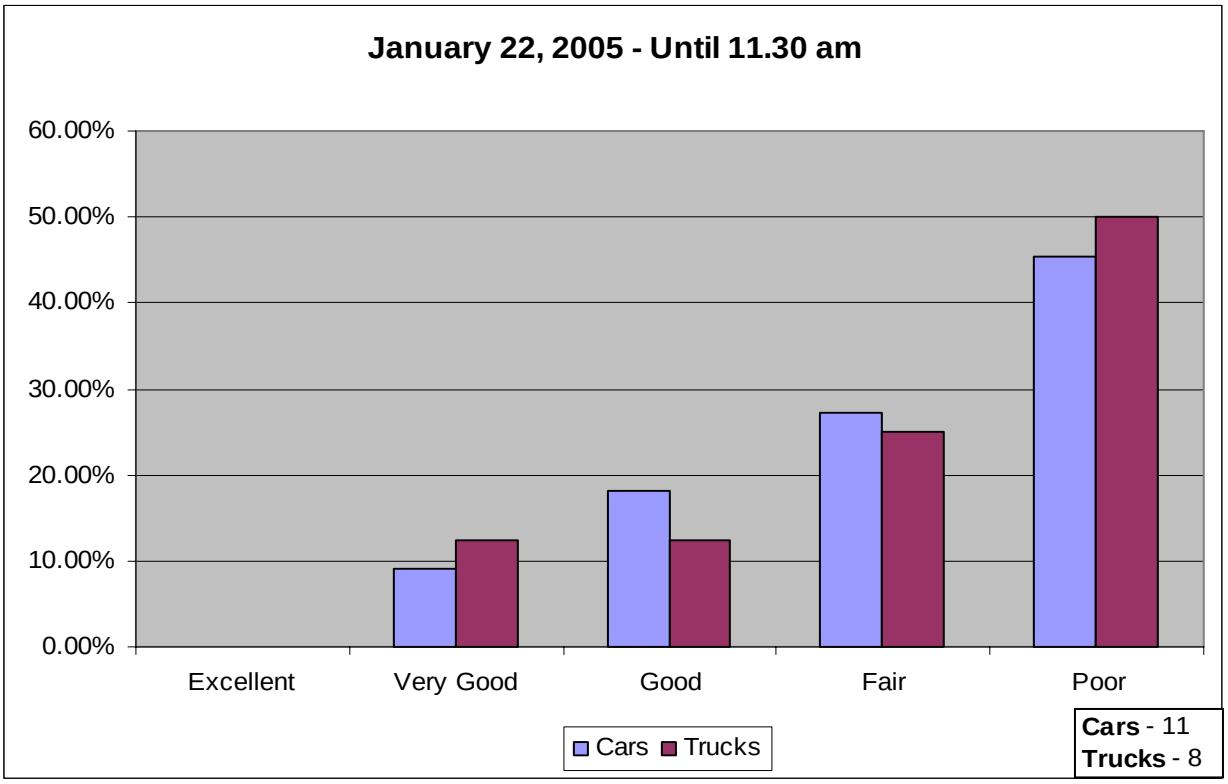

Figure 122: Rating of the road clearing and treatment (until 11.30 am).

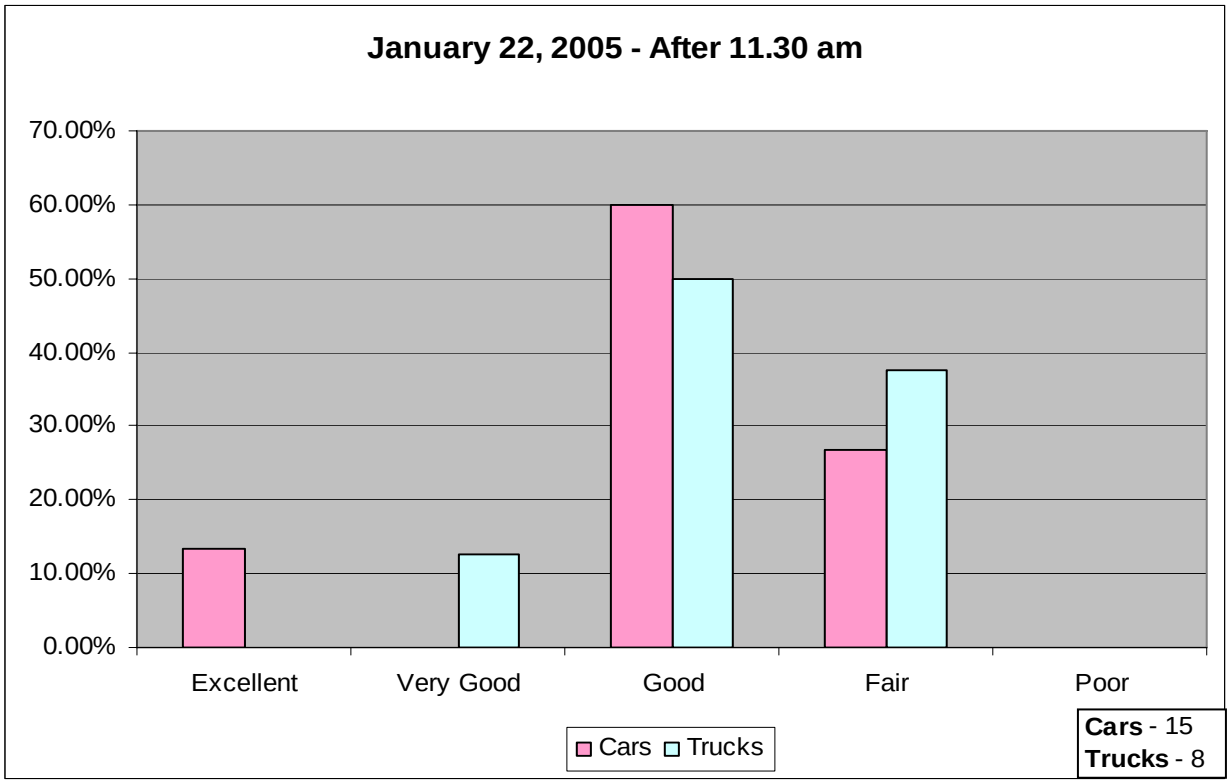

Figure 123: Rating of the road clearing and treatment (after 11.30 am).

Question 15

In question 15, the drivers were asked to rank the stress factors which they experienced during their travel for the last few miles. Before 11.30 am, most of the respondents considered driving stressful because of the snow on the highway in the driving lane. But after 11.30 am, equal percentage of drivers experienced stress because of snow on the highway and also due to traffic around them. Table 83 represents the total responses of drivers who experienced stress. Table 84 and Table 85 show the ranking of stress factors experienced by the drivers during both the periods.
Table 86 represents the total responses of car and truck drivers who experienced stress on both the days. Table 87 and Table 40 show the ranking of the stress factors experienced by the car and truck drivers who arrived before 11.30 am. Similarly, Table 88 and Table 89 show the ranking of stress factors for both car and truck drivers who arrived after 11.30 am.

Table 83 . Responses about the stress factors drivers experienced.

Date: 01/22/2005		Until 11.30am	After 11.30am
		# Respondents	# Respondents
Stress factors experienced in the last few miles or so of your drive:	Not stressful, similar to normal driving	5	8
	Stressful because of falling snow or other precipitation	3	4
	Stressful because of blowing snow and reduced visibility	5	4
	Stressful because of the traffic around you	4	10
	Stressful because of fog	0	1
	Stressful because of the snow on the highway in your driving lane	10	10
	Stressful because of the icy conditions in your driving lane	1	7

Table 84 . Ranking of Stress Factors which Drivers Experienced (Until 11.30 am).

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	5	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	2	0	1	0	0	0	0
Stressful because of blowing snow and reduced visibility	2	3	0	0	0	0	0
Stressful because of the traffic around you	3	1	0	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	6	4	0	0	0	0	0
Stressful because of the icy conditions in your driving lane	1	0	0	0	0	0	0

Table 85 . Ranking of Stress Factors which Drivers Experienced (After 11.30 am).

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	8	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	1	0	2	1	0	0	0
Stressful because of blowing snow and reduced visibility	0	3	1	0	0	0	0
Stressful because of the traffic around you	7	1	0	0	1	1	0
Stressful because of fog	1	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	5	3	1	0	1	0	0
Stressful because of the icy conditions in your driving lane	1	4	1	1	0	0	0

Table 86 . Responses about the stress factors car and truck drivers experienced.

Date: 01/22/2005		Until 11.30 am		After 11.30 am	
Vehicle Type		Cars	Trucks	Cars	Trucks
		#	#	#	#
Stress factors experienced in the last few miles or so of your drive:	Not stressful, similar to normal driving	2	3	6	2
	Stressful because of falling snow or other precipitation	0	3	2	2
	Stressful because of blowing snow and reduced visibility	2	3	4	0
	Stressful because of the traffic around you	3	1	5	5
	Stressful because of fog	0	0	1	0
	Stressful because of the snow on the highway in your driving lane	7	3	6	4
	Stressful because of the icy conditions in your driving lane	1	0	5	2

Table 87 . Ranking of stress factors which car drivers experienced (until 11.30 am).

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	2	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	0	0	0	0	0	0	0
Stressful because of blowing snow and reduced visibility	2	0	0	0	0	0	0
Stressful because of the traffic around you	2	1	0	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	4	3	0	0	0	0	0
Stressful because of the icy conditions in your driving lane	1	0	0	0	0	0	0

Table 88 . Ranking of stress factors which truck drivers experienced (until 11.30 am).

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	3	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	2	0	1	0	0	0	0
Stressful because of blowing snow and reduced visibility	0	3	0	0	0	0	0
Stressful because of the traffic around you	1	0	0	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	2	1	0	0	0	0	0
Stressful because of the icy conditions in your driving lane	0	0	0	0	0	0	0

Table 89 . Ranking of stress factors which car drivers experienced (after 11.30 am).

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	6	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	0	0	1	1	0	0	0
Stressful because of blowing snow and reduced visibility	0	3	1	0	0	0	0
Stressful because of the traffic around you	3	0	0	0	1	1	0
Stressful because of fog	1	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	4	1	0	0	1	0	0
Stressful because of the icy conditions in your driving lane	1	3	0	1	0	0	0

Table 90 . Ranking of stress factors which truck drivers experienced (after 11.30 am).

Factors	Rank						
	1	2	3	4	5	6	7
Not stressful, similar to normal driving	2	0	0	0	0	0	0
Stressful because of falling snow or other precipitation	1	0	1	0	0	0	0
Stressful because of blowing snow and reduced visibility	0	0	0	0	0	0	0
Stressful because of the traffic around you	4	1	0	0	0	0	0
Stressful because of fog	0	0	0	0	0	0	0
Stressful because of the snow on the highway in your driving lane	1	2	1	0	0	0	0
Stressful because of the icy conditions in your driving lane	0	1	1	0	0	0	0

Question 16

The drivers were asked about how difficult it was to drive the last few miles during the storm. 37% of the drivers who arrived before 11.30 am and 39% who arrived after 11.30 am felt it was moderately difficult to drive on I-76 Westbound. After 11.30 am, about 33% of car drivers and 38% of truck drivers said that the driving was not difficult in the I-76 stretch of the road. Table 91 shows the responses and percentages and Figure 124 represents them graphically. Table 92 gives the number of responses and percentages for car and truck drivers separately. Figure 125 and Figure 126 represents them graphically for both the periods.

Table 91 . Responses on difficulty of driving on I-76 westbound.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
How difficult was it to drive the last few miles or so of this freeway?	Not difficult	1	5.26%	8	34.78%
	Just a bit more difficult than under clear and dry conditions	6	31.58%	5	21.74%
	Moderately difficult	7	36.84%	9	39.13%
	Very difficult	5	26.32%	1	4.35%

Table 92 . Responses on difficulty of driving on I-76 westbound.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How difficult was it to drive the last few miles or so of this freeway?	Not difficult	0	0.00%	1	12.50%	5	33.33%	3	37.50%
	Just a bit more difficult than under clear and dry conditions	3	27.27%	3	37.50%	3	20.00%	2	25.00%
	Moderately difficult	3	27.27%	4	50.00%	6	40.00%	3	37.50%
	Very difficult	5	45.45%	0	0.00%	1	6.67%	0	0.00%

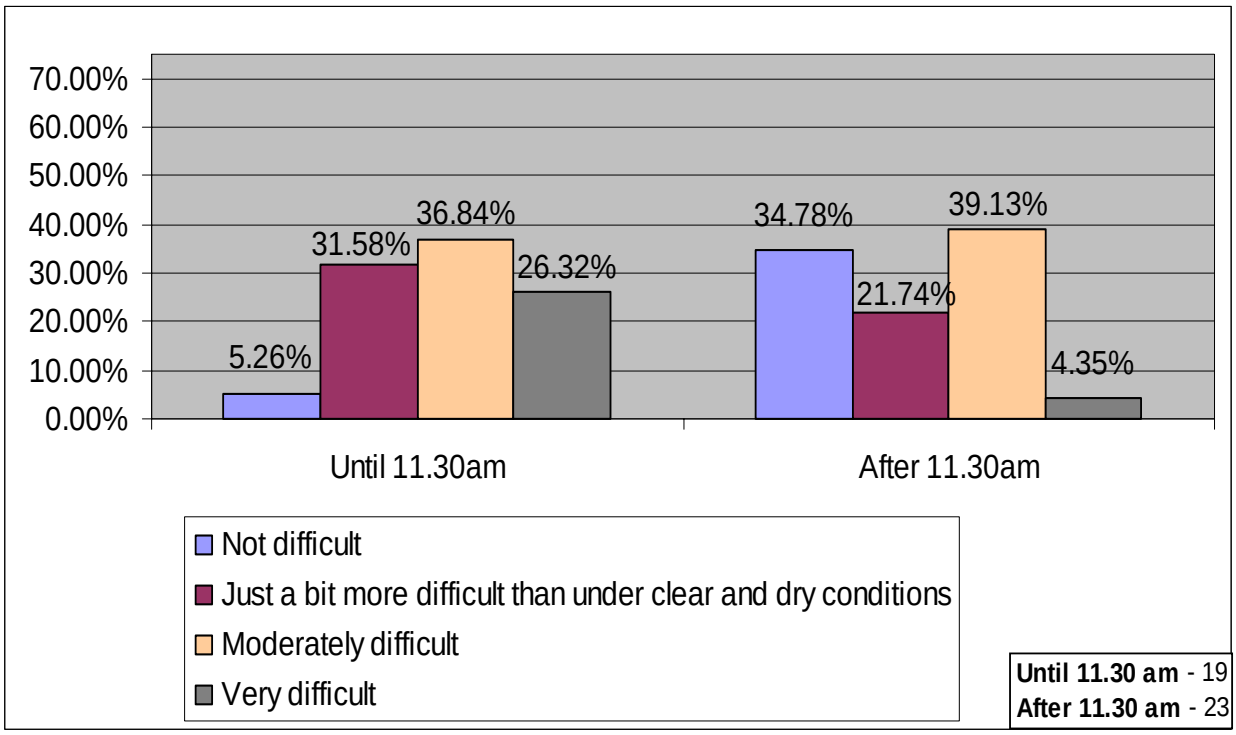

Figure 124: Response percentages of drivers about driving difficulty.

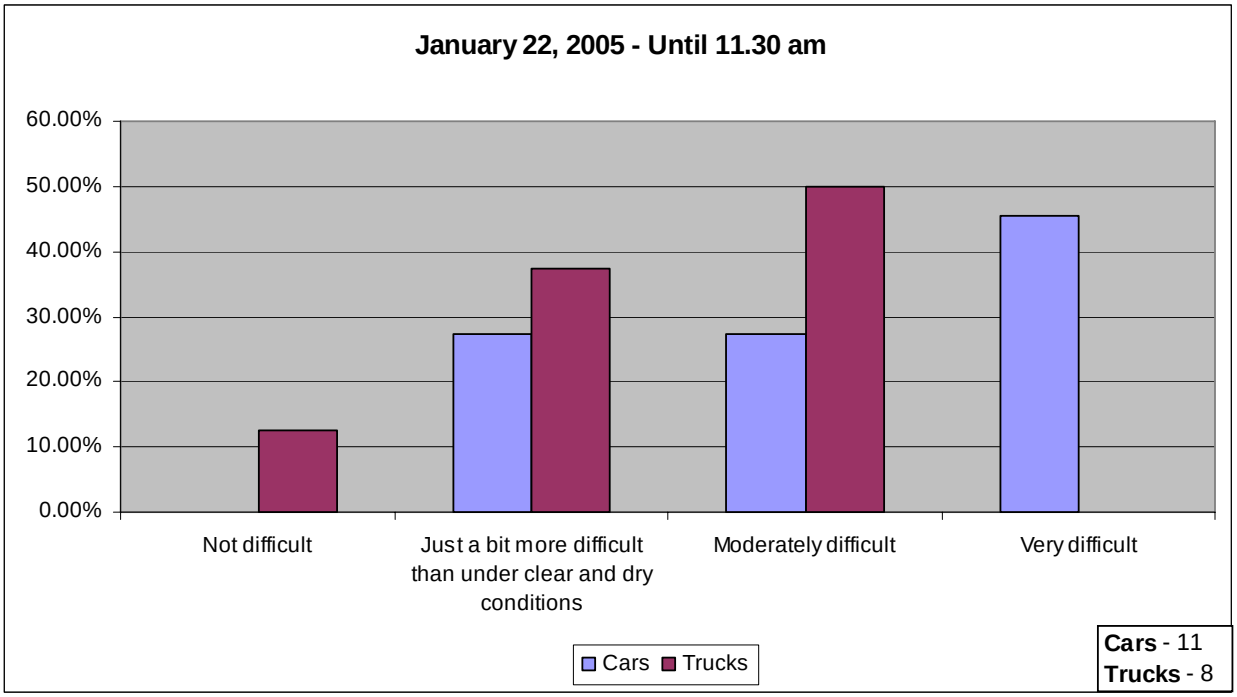

Figure 125: Response percentages of drivers about driving difficulty who arrived before 11.30 am.

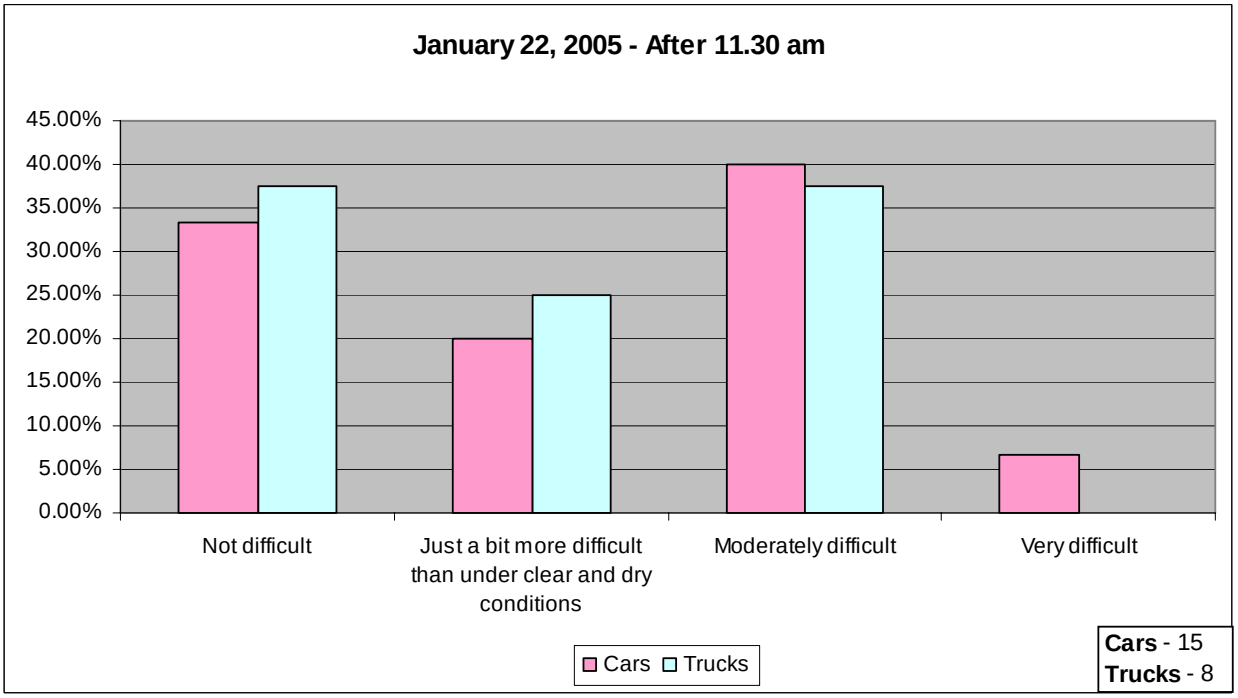

Figure 126: Response percentages of drivers about driving difficulty who arrived after 11.30am.

Question 17

Question 17 asked how safe the drivers felt when they drove on the freeway for the last few miles during the storm. 42% of drivers who arrived before 11.30 am felt they were moderately safe driving on I-76 Westbound. After 11.30 am 26% felt they were moderately safe, 35% felt they were very safe and another 35% felt they were just a bit less safe than under clear and dry conditions. Table 93 gives the number of responses and percentages while Figure 127 shows them graphically.
Until 11.30 am, about 36% of car drivers and 50% of truck drivers said that they felt moderately safe while driving on I-76 Westbound. 25-27% of said they were very safe driving on I-76. After 11.30 am, high percentage of drivers replied that they felt very safe and/or just a bit less safe than under clear and dry conditions. Table 94 gives the number of responses and percentages for both car and trucks drivers. Figure 128 and Figure 129 represents them graphically for both the periods.

Table 93 . Responses on how safe the drivers feel while driving on I-76 westbound.

Date: 01/22/2005		Until 11.30am		After 11.30am	
		# Respondents	Percentage	# Respondents	Percentage
How safe do you feel driving the last few miles or so of this freeway ?	Very safe	5	26.32%	8	34.78%
	Just a bit less safe than under clear and dry conditions	2	10.53%	8	34.78%
	Moderately safe	8	42.11%	6	26.09%
	Not safe	4	21.05%	1	4.35%

Table 94 . Responses on how safe the drivers feel while driving on I-76 westbound.

Date: 01/22/2005		Until 11.30 am				After 11.30 am			
Vehicle Type		Cars		Trucks		Cars		Trucks	
		#	%	#	%	#	%	#	%
How safe do you feel driving the last few miles or so of this freeway?	Very safe	3	27.27%	2	25.00%	7	46.67%	1	12.50%
	Just a bit less safe than under clear and dry conditions	1	9.09%	1	12.50%	4	26.67%	4	50.00%
	Moderately safe	4	36.36%	4	50.00%	3	20.00%	3	37.50%
	Not safe	3	27.27%	1	12.50%	1	6.67%	0	0.00%

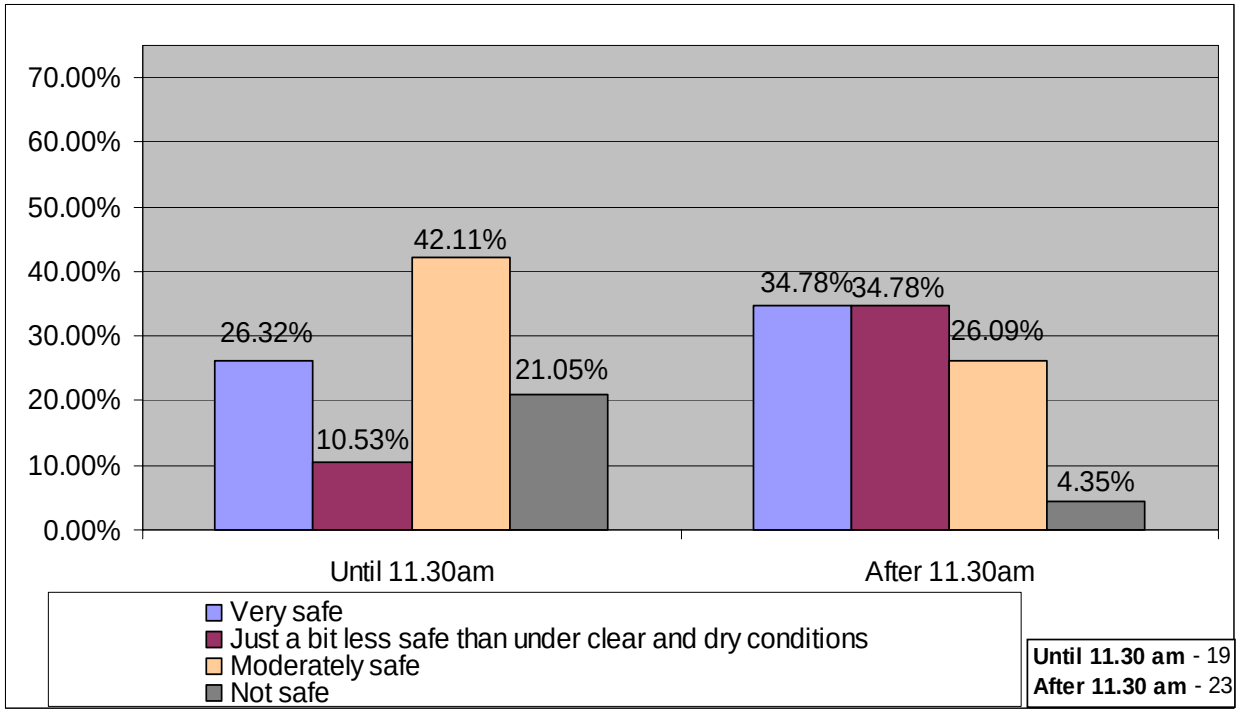

Figure 127: Response percentage of how safe the drivers feel driving on I-76.

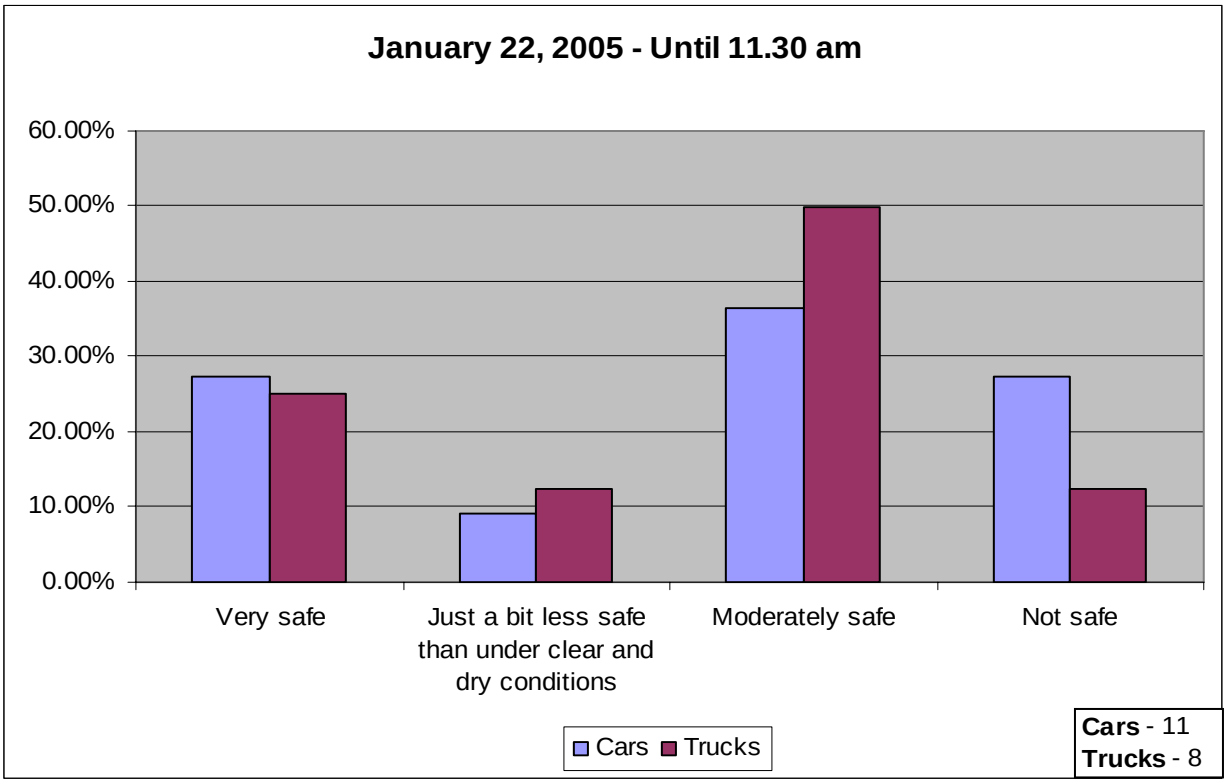

Figure 128: Response percentage of how safe the drivers feel driving on I-76 (until 11.30 am).

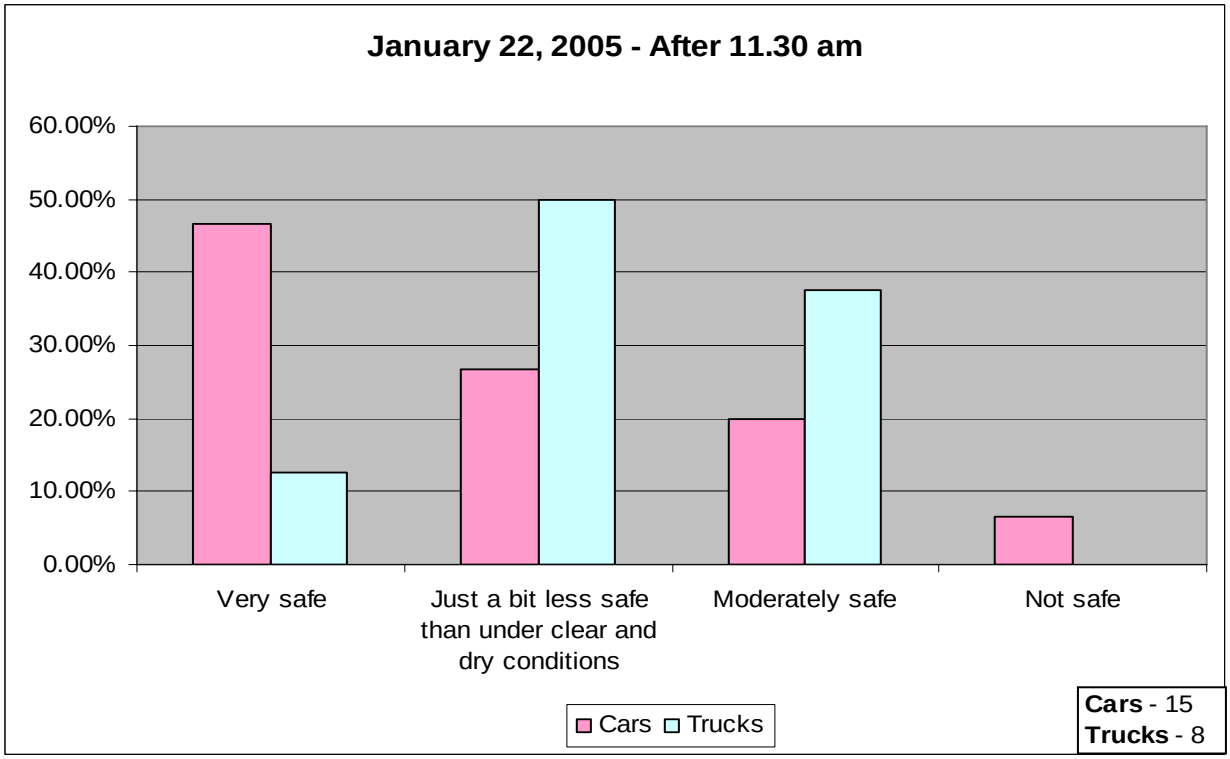

Figure 129: response percentage of how safe the drivers feel driving on I-76 (after 11.30 am).

Question 18

Question 18 was directed to the truck drivers only which asked the estimated percentage of the truck load they are carrying. 50 % of the truck drivers before 11.30 am and 62.5% of truck drivers after 11.30 am replied that they were carrying full load. Table 95 shows the truck drivers' responses for both the periods and Figure 130 shows them graphically.

Table 95 . Estimated percentage of load carried by trucks.

Date: 01/22/2005		Trucks			
Vehicle Type		Until 11.30 am		After 11.30 am	
		#	%	#	%
What is the estimated percentage of your load?	No load, empty	0	0.00%	1	12.50%
	25% of full load or weight	0	0.00%	1	12.50%
	50% of full load or weight	3	37.50%	0	0.00%
	75% of full load or weight	1	12.50%	1	12.50%
	Full load, weight	4	50.00%	5	62.50%

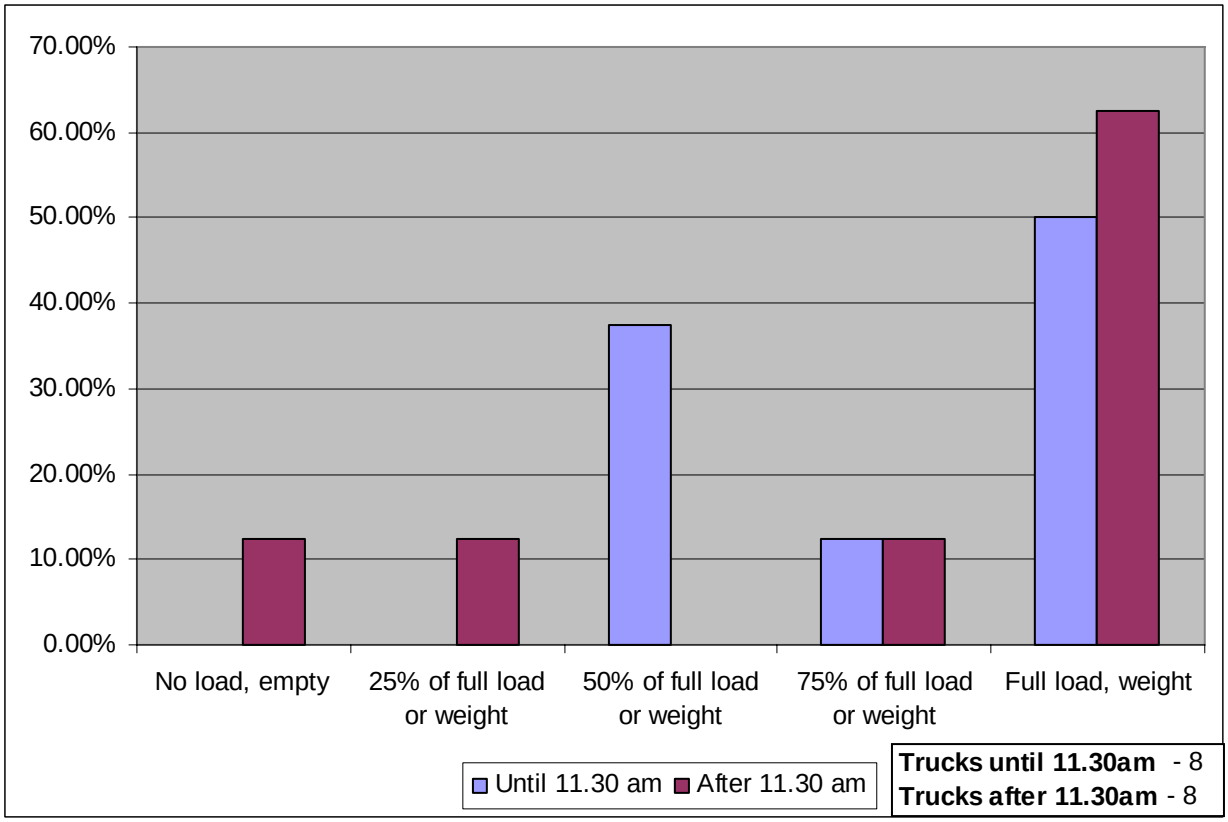

Figure 130: Graph showing the expected load percentage carried by trucks.

10. DISCUSSION OF RESULTS & CONCLUSIONS FOR THE SURVEY ON I-76

The driver survey at the rest area 04-36 on I-76 in Portage County was successfully conducted and evaluated. The procedure followed during the survey worked quite well but the response rate was not as good as we expected probably because of the less number of people driving on I-76 mainly due to the weekend. Most of the drivers who were surveyed were cooperative in answering the questions providing their valuable time. It was observed that driving and weather conditions were bad during the morning of January 22 and things started to improve gradually in the later part of the day. This can be seen in the reduced speeds of drivers who were aware of the potential hazardous conditions prevailing on the road It should be noted that this snow storm was a fairly severe snow storm. As mentioned earlier in the results obtained from the driver survey on I-271 due to the lack of winter storms during the 2004, 2005 and 2006 years additional driver surveys could not be conducted in less severe or under more normal winter storm conditions during the duration of the study to obtain data for a more balanced set of winter storm and snow conditions.

The RWIS speed and surface temperature graphs obtained from station number 91 provided in the previous sections give an insight to the conditions on I-76 Westbound. As the road conditions deteriorated some of the drivers reduced their speed from 60 mph to 40 mph in the morning of 22nd. Drivers increased their speed as the weather improved later in the day. The surface temperature also fell below 32^{o}F over a period of more than 36 hours. The number of people using the passing lane is very much less when compared to those using driving lane on January 22. This can be correlated to the high response percentage of drivers using right lane for most part of the time and visibility of wheel tracks in the right lane. The plots from the National Climatic Data Center (NCDC) show that there was snowfall in the region on the 22nd. The data obtained from RWIS sensors (Station No. 91) were not accurate as observed in the graphs. The RWIS sensors reported the number of vehicles passing through as more than 100 or 150 vehicles in a given 5-minute time interval. This is probably caused by the pavement sensors reporting data intermittently. If a pavement sensor cannot report data during a five-minute interval, it continues counting cars and sends the total count when it can, thus a large count may represent an accumulation over several 5-minute periods. Also the surface temperature data may not be accurate as some of the values remain at the same temperature for an extended period of time. The pictures taken on the both periods documented the typical condition of the road. In the morning, roads were covered with snow while later in the day the roads were clear as there was less or no snow. Though wheel tracks were visible in the morning period the primary concern for drivers was the slippery road surface and lack of visibility due to falling snow.

The survey respondents were mainly male. 9% of the car drivers responded to the survey was female and all of the truck drivers surveyed were male. The car drivers have been driving for 30 years on the average and the truck drivers have been driving 22 years on the average. About 80% of the drivers drive by I-76 either a few times a month, once per week, more than once per week or daily. About 58-65% of the respondents were driving an automobile, SUV or pick-up truck and about 35-42% of them drove large trucks or tractor-trailers. About 62 % of the car drivers used two wheel drives while 38% used four-wheel drive. About 51% of the truck drivers used the drive system available within the trucks. All the drivers had their headlights on irrespective of the period of time. It was noted that most of the drivers drove in the right lane, all car drivers and 94% of truck drivers.

Most respondents drove below the speed limit. In the morning around 45% of the car drivers drove 10-20 mph below the speed limit while 36% of them drove 5-10 mph below the speed limit. About 50% of the truck drivers drove below the more than 20 mph below the speed limit in

the morning. As things started to improve from noon, drivers started to increase their speed. 60% of car drivers drove 5-10 mph below the speed limit and 63% of truck drivers drove about the speed limit on I-76 Westbound. The main factors opined for reduced speed were the snow and ice on roads along with the reduced visibility on 22nd both for the car and truck drivers. However later on after noon on January 22 some of the drivers were having no trouble driving and some of them thought that traffic around them was the factor to reduce their speed. All the car drivers and 75% of the truck drivers opined that the pavement was 60% or less clear from edgeline to edgeline in the morning of 22nd as the roads were covered with snow and after 11.30 am 47% of car drivers and 50% of truck drivers opined that the pavement was 60% or less clear from edgeline to edgeline. More drivers who arrived after noon thought that the pavement was clearer. The wheel tracks were visible to most drivers. About 79% of the drivers who arrived in the morning replied that they could see the wheel track in the right or driving lane only as the roads were covered with snow. 39% of the drivers who arrived after 11.30 am replied that they could see wheel tracks in the right lane only while 35% said that they could see the wheel tracks on both the lanes, which can be confirmed by the pictures shown before.

Most of the drivers surveyed were of the opinion that the clearing and treatment of the roads was fair or good. In the morning 47% of the drivers opined that the clearing and treatment of the road was poor whereas after 11.30 am 57% of the drivers opined that the clearing and the treatment of the road was good. The snow on the roads made driving stressful as indicated by the results. On 22nd both the car and truck drivers opined that the driving was stressful because of the snow on the highway. Some drivers even thought that traffic around them was stressful. More people responded that they experienced stress because of snow and lack of visibility in their driving lane. Also some of the drivers did not experience stress as the roads were clear in the later part of the day. The largest percentage of drivers replied that it was moderately difficult to drive on roads and that they felt that these conditions were moderately safe or just a bit little safe than under normal conditions for driving. About 50-62% of the truck drivers were carrying full load.

The results over the two periods (7:30 AM-11:30 AM and 11:30 AM-6:30 PM on January 22nd, 2005) show that there was some difference between them. As things started to improve after noon on January 22, better responses were given when compared to those given in the morning. Also, the responses by car and truck drivers were not significantly different. The graphs show similar response percentages for all questions. All the results correlate to the graphs from RWIS, NCDC and the pictures shown before.

This driver survey performed in the winter storm provided insight into the driver speeds and their relationship with the clearing and maintenance of the roads. As the road conditions deteriorated, the drivers felt less secure and considerably decreased their speeds. When these conditions prevail, good maintenance and clearing of the roads promptly would improve driver safety and their confidence. This helps in maintaining the traffic flow continuously without considerably reducing their driving speeds.

11. SUMMARY OF THE DRIVER SURVEYS:

Table 96 . Summary of the total number of driver responses for the driver surveys conducted in the study at rest area 04-440 on I-271 Southbound and at rest area 04-36 I-76 Westbound.

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
			12/22/04	12/23/05	01/22/05	01/22/06
					Until	After
					11:30 AM	11:30 AM
1	Arrival time	Daylight	9	40	18	18
		Dark/Night time	31	0	0	4
		Dawn	0	0	1	0
		Dusk	12	0	0	1
2	Gender	Male	43	36	18	20
		Female	9	4	1	3
3	Drving experience(Average)	Number of years	25.94	24.88	27	26.22
4	Frequency of the use of the road	More than once a week	4	1	3	5
		Daily	9	1	3	3
		Once a week	6	5	1	2
		A few times a month	15	13	8	7
		Rarely	18	20	4	6
5	Type of vehicle	Automobile/Van	25	19	25	19
		SUV	6	9	6	9
		Pick-up	5	2	5	2
		Large truck	2	0	2	0
		Tractor trailer	14	10	14	10
		Other	0	0	0	0
6	Drive system used	Two wheel drive	31	24	7	17
		Four wheel drive	10	9	7	3
		Truck drive system	11	7	5	3
7	Headlights	On	52	39	19	23
		Off	0	0	0	0
8	Lane of travel for the last few miles	Mostly in the right lane	40	28	18	23
		Mostly in the left or passing lane	11	10	1	0
		Both/Not sure	1	2	0	0
9	Speed of travel for the last few miles	About the speed limit	8	4	0	8
		Slightly below the speed limit(5-10 mph)	6	6	7	11
		Consderably below the speed limit(10-20 mph)	13	15	6	1

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
		Very slowly(20 mph below the speed limit)	25	15	6	3
10	Ranking of the factors that reduced the driving speed	Traffic around(front and back)	27	18	5	7
		Visibility conditions due to falling snow,freezing rain,or other precipation	34	12	4	6
		Visibility conditions due to blowing snow	9	3	11	4
		Visibility conditions due to fog	4	2	0	0
		Road surface conditions,mainly snow on the road	41	26	12	12
		Icy and slippery road surface	20	29	9	10
		Construction or law enforcement activity	5	1	2	1
		Other	0	0	0	0
		None,Drving was fine	0	0	0	8
11	Visibility of the road surface for the last few miles	100 % clear from edgeline to edgelines	0	0	0	2
		90 % clear from edgeline to edgelines	2	0	0	4
		80 % clear from edgeline to edgelines	3	1	0	2
		70 % clear from edgeline to edgelines	2	5	2	4
		60 % clear from edgeline to edgelines	45	34	17	11
12	Condition of the lane driven	Clear	0	0	0	4
		Snow covered	40	16	16	8
		Snow covered in spots	5	6	4	9
		Drifted snow	0	1	1	2
		Icy	4	12	0	2
		Icy in spots	6	7	2	4
		Slush covered	11	12	0	5
		Blocked	0	2	0	0
13	Visibility of the wheel tracks	No tracks- road covered with snow	5	5	1	2
		Wheel tracks in the right(driving)lane only	20	16	15	9

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
		Wheel tracks in the left(passing)lane only	1	0	1	0
		Wheel tracks in both lanes	26	19	2	8
14	Rating of the clearing and treatment for the last few miles during the storm	Excellent	0	2	0	2
		Very good	6	3	2	1
		Good	10	9	3	13
		Fair	12	15	5	7
		Poor	24	11	9	0
15	Stress factors experienced in the last few miles	Not stressfull,similar to normal driving	11	5	5	8
		Stressful because of falling snow or other precipitation	19	5	3	4
		Stressful because of blowing snow and reduced visibility	10	5	5	4
		Stressful because of traffic around you	21	14	4	10
		Stressful because of the fog	1	0	0	1
		Stressful because of snow on the highway in your driving lane	30	14	10	10
		Stressfull because of the icy conditions in your driving lane	18	28	1	7
16	Difficulty level of driving for the last few miles of the freeway	Just a bit more difficult than under clear and dry conditions	2	1	1	8
		Not difficult	9	5	6	5
		Moderalty difficult	27	27	7	9
		Very difficult	14	7	5	1
17	Safety level felt by the driver	Very safe	5	3	5	8
		Just a bit less safe than unde clear and dry conditions	15	7	2	8
		Moderatly safe	19	23	8	6
		Not safe	13	7	4	1

Table 97 . Summary of the car driver responses for the driver surveys conducted in the study at rest area 04-440 on I-271 Southbound and at rest area 04-36 I-76 Westbound.

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
			12/22/04	12/23/05	01/22/05	01/22/06
					Until	After
					11:30 AM	11:30 AM
1	Arrival time	Daylight	6	30	10	13
		Dark/Night time	21	0	0	1
		Dawn	0	0	1	0
		Dusk	9	0	0	1
2	Gender	Male	27	26	10	12
		Female	9	4	1	3
3	Drving experience(Average)	Number of years	28.64	28.13	34.27	26.27
4	Frequency of the use of the road	More than once a week	3	1	2	2
		Daily	7	1	0	4
		Once a week	2	2	1	1
		A few times a month	8	8	4	2
		Rarely	16	18	4	6
5	Type of vehicle	Automobile/Van	25	19	5	7
		SUV	6	9	3	4
		Pick-up	5	2	3	4
		Large truck	0	0	0	0
		Tractor trailer	0	0	0	0
		Other	0	0	0	0
6	Drive system used	Two wheel drive	27	21	5	12
		Four wheel drive	9	9	6	3
		Truck drive system	0	0	0	0
7	Headlights	On	36	30	11	15
		Off	0	0	0	0
8	Lane of travel for the last few miles	Mostly in the right lane	25	22	11	15
		Mostly in the left or passing lane	11	8	0	0
		Both/Not sure	0	0	0	0
9	Speed of travel for the last few miles	About the speed limit	3	3	0	3
		Slightly below the speed limit(5-10 mph)	4	5	4	9
		Consderably below the speed limit(10-20 mph)	10	11	5	0
		Very slowly(20 mph below the speed limit)	19	11	2	3
10	Ranking of the factors that reduced the driving speed	Traffic around(front and back)	19	13	2	3

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
		Visibility conditions due to falling snow,freezing rain,or other precipation	26	10	1	4
		Visibility conditions due to blowing snow	6	2	7	4
		Visibility conditions due to fog	2	1	0	0
		Road surface conditions,mainly snow on the road	29	20	6	10
		Icy and slippery road surface	13	21	5	8
		Construction or law enforcement activity	3	0	1	0
		Other	0	0	0	0
		None,Drving was fine	0	0	0	4
11	Visibility of the road surface for the last few miles	100 % clear from edgeline to edgelines	0	0	0	2
		90 % clear from edgeline to edgelines	1	0	0	2
		80 % clear from edgeline to edgelines	1	1	0	0
		70 % clear from edgeline to edgelines	1	4	0	4
		60 % clear from edgeline to edgelines	33	25	11	7
12	Condition of the lane driven	Clear	0	0	0	2
		Snow covered	27	10	9	6
		Snow covered in spots	3	6	3	6
		Drifted snow	0	1	1	2
		Icy	2	10	0	2
		Icy in spots	4	6	1	4
		Slush covered	9	10	0	4
		Blocked	0	2	0	0
13	Visibility of the wheel tracks	No tracks- road covered with snow	4	4	0	1
		Wheel tracks in the right(driving)lane only	18	14	10	7
		Wheel tracks in the left(passing)lane only	1	0	0	0
		Wheel tracks in both lanes	13	12	1	5

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
14	Rating of the clearing and treatment for the last few miles during the storm	Excellent	0	2	0	2
		Very good	6	3	1	0
		Good	10	9	2	9
		Fair	12	15	3	4
		Poor	24	11	5	0
15	Stress factors experienced in the last few miles	Not stressfull,similar to normal driving	7	4	2	6
		Stressful because of falling snow or other precipitation	16	2	0	2
		Stressful because of blowing snow and reduced visibility	9	4	2	4
		Stressful because of traffic around you	14	10	3	5
		Stressful because of the fog	1	0	0	1
		Stressful because of snow on the highway in your driving lane	21	11	7	6
		Stressfull because of the icy conditions in your driving lane	15	21	1	3
16	Difficulty level of driving for the last few miles of the freeway	Just a bit more difficult than under clear and dry conditions	2	1	0	5
		Not difficult	4	4	3	3
		Moderalty difficult	21	22	3	6
		Very difficult	9	3	5	1
17	Safety level felt by the driver	Very safe	4	3	3	7
		Just a bit less safe than unde clear and dry conditions	9	6	1	4
		Moderatly safe	14	16	4	3
		Not safe	9	5	3	1

Table 98 . Summary of the truck driver responses for the driver surveys conducted in the study at rest area 04-440 on I-271 Southbound and at rest area 04-36 I-76 Westbound.

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
			12/22/04	12/23/05	01/22/05	01/22/06
					Until	After
					11:30 AM	11:30 AM
1	Arrival time	Daylight	3	10	8	5
		Dark/Night time	10	0	0	3
		Dawn	0	0	0	0
		Dusk	3	0	0	0
2	Gender	Male	16	10	8	8
		Female	0	0	0	0
3	Drving experience(Average)	Number of years	19.88	15.1	17	26.13
4	Frequency of the use of the road	More than once a week	1	0	1	1
		Daily	2	0	3	1
		Once a week	4	3	0	1
		A few times a month	7	5	4	5
		Rarely	2	2	0	0
5	Type of vehicle	Automobile/Van	0	0	0	0
		SUV	0	0	0	0
		Pick-up	0	0	0	0
		Large truck	2	0	1	0
		Tractor trailer	14	10	7	8
		Other	0	0	0	0
6	Drive system used	Two wheel drive	4	3	2	5
		Four wheel drive	1	0	1	0
		Truck drive system	11	7	5	3
7	Headlights	On	16	9	8	8
		Off	0	1	0	0
8	Lane of travel for the last few miles	Mostly in the right lane	15	6	7	8
		Mostly in the left or passing lane	0	2	1	0
		Both/Not sure	1	2	0	0
9	Speed of travel for the last few miles	About the speed limit	5	1	0	5
		Slightly below the speed limit(5-10 mph)	2	1	3	2
		Consderably below the speed limit(10-20 mph)	3	4	1	1
		Very slowly(20 mph below the speed limit)	6	4	4	0
10	Ranking of the factors that reduced the driving speed	Traffic around(front and back)	8	5	3	4

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
		Visibility conditions due to falling snow,freezing rain,or other precipation	8	2	3	2
		Visibility conditions due to blowing snow	3	1	4	0
		Visibility conditions due to fog	2	1	0	0
		Road surface conditions,mainly snow on the road	12	6	6	2
		Icy and slippery road surface	7	8	4	2
		Construction or law enforcement activity	2	1	1	1
		Other	0	0	0	0
		None,Drving was fine	0	0	0	4
11	Visibility of the road surface for the last few miles	100 % clear from edgeline to edgelines	0	0	0	0
		90 % clear from edgeline to edgelines	1	0	0	2
		80 % clear from edgeline to edgelines	2	0	0	2
		70 % clear from edgeline to edgelines	1	1	2	0
		60 % clear from edgeline to edgelines	12	9	6	4
12	Condition of the lane driven	Clear	0	0	0	2
		Snow covered	13	6	7	2
		Snow covered in spots	2	0	1	3
		Drifted snow	0	0	0	0
		Icy	2	2	0	0
		Icy in spots	2	1	1	0
		Slush covered	2	2	0	1
		Blocked	0	0	0	0
13	Visibility of the wheel tracks	No tracks- road covered with snow	1	1	1	1
		Wheel tracks in the right(driving)lane only	2	2	5	2
		Wheel tracks in the left(passing)lane only	0	0	1	0
		Wheel tracks in both lanes	13	7	1	3

No	Question	Response Option	I-271 South Bound		I-76 west Bound	
14	Rating of the clearing and treatment for the last few miles during the storm	Excellent	0	1	0	0
		Very good	3	0	1	1
		Good	2	2	1	4
		Fair	4	2	2	3
		Poor	7	5	4	0
15	Stress factors experienced in the last few miles	Not stressfull,similar to normal driving	4	1	3	2
		Stressful because of falling snow or other precipitation	3	3	3	2
		Stressful because of blowing snow and reduced visibility	1	1	3	0
		Stressful because of traffic around you	7	4	1	5
		Stressful because of the fog	0	0	0	0
		Stressful because of snow on the highway in your driving lane	9	3	3	4
		Stressfull because of the icy conditions in your driving lane	3	7	0	2
16	Difficulty level of driving for the last few miles of the freeway	Just a bit more difficult than under clear and dry conditions	0	0	3	2
		Not difficult	5	1	1	3
		Moderalty difficult	6	5	4	3
		Very difficult	5	4	0	0
17	Safety level felt by the driver	Very safe	1	0	2	1
		Just a bit less safe than unde clear and dry conditions	6	1	1	4
		Moderatly safe	5	7	4	3
		Not safe	4	2	0	0

Table 96, Table 97 and Table 98 summarize the total number of responses, car driver responses and truck driver responses respectively obtained for the both driver surveys. It can be seen from the summary tables and the results of the drivers surveys that the responses obtained for car and truck drivers were fairly close to each other and their perception of the road and driving conditions are almost the same.

12. ANALYSIS OF THE AVERAGE SPEEDS OBTAINED IN THIS STUDY AND THE OTHER TWO STUDIES

Six freeway sites and two city streets were analyzed for the average speeds obtained before a snow storm, during the snow storm and after the snow storm. Two of the six sites were in Ohio, one was in Wisconsin [1] and three sites were in Switzerland [2]. The two city sites analyzed for the study were in Switzerland [2]. The analysis for the two sites in Ohio was performed by Ohio University after driver surveys were conducted at the sites during a winter storm. The average speed values obtained are tabulated in the Table 99.

Effect of winter services:

According to [2], the decision of the winter services to mechanically remove the snow from the roadway using a snow plough or to apply salt on the roadway depends on a lot of factors. Condition of the roadway, thickness of snow, kind of snow and intensity of snow play a vital role in winter maintenance decision making. The road temperature, remaining salt on the roadway determines the further treatment required for the roadway. The amount of salt per square foot/square meter to be applied on the roadway is affected by the factors mentioned above and can also be determined by the maneuverability on the roadway.

Based on statements by [2] on city streets, traffic needs to be cleared to prevent crashes but with a fixed plan for clearing traffic results in deviations depending on the situation. The clearing traffic obstructs the winter maintenance which is why optimum salt application is not achieved. The application generally lasts for 2-3 hours depending on the length of the roadway, traffic density and type of equipment used. The success of the salt application also depends on the driving personal and dispatch controller. They must fulfill their task efficiently to create a normally passable salt-wet roadway also taking care of the economic implication involved in the process.

Further, [2] states that in continuous winter storm events, winter maintenance can defuse the situation temporarily which is why further application of the salt becomes necessary. With continuous snow clearance and salt application a traffic break down situation can be avoided. With out any snow clearance, chaotic situation can develop. The maintenance crew also need to makes sure that snow doesn't accumulate a lot on the salted roadway which makes further treatments more difficult.

As pointed out by [2] a clear speed rise is observed on the roadway ideally after one hour of the arrival of the winter services. The speed rise can be faster or slower depending on the weather conditions after the treatment, pavement roughness, density of traffic and air temperature gradient. Speed recovery duration is proposed to be a key element in determining the level of winter maintenance according to [1]. Speed recovery duration is defined by [1] as the time between the "snow event stop" and the "vehicle speed recovered to normal". The problem with the speed recovery duration is that it is not available in real time (only available after recovery is completed) as average speeds reported by the RWIS system are available every five minutes to make it possible for the winter maintenance decision maker to call out for winter maintenance actions while the snow storm or other winter emergency conditions are in progress. It can be seen that people drive carefully in winter roadway conditions. This shows driver travel safely and homogenously maintaining the minimum headway as compared with the dry roadway conditions. A clear conclusion on the speeds during winter conditions can't be optimally decided because of the variations in driving patterns.

Table 99 . Summary of the average speeds obtained in the study for sites in USA and Switzerland [1], [2].

No	Site Description	Date	Average speed before snow	Lowest avg speed during winter storm	Average lowest speed during winter storm as a % of avg speed before snow	Average speed in wet/salted pavement condition as a % of avg speed before snow	50 % speed after one hour after the event	Time to reach lowest avg speed
			mph(kmph)	mph(kmph)	%	%	mph(kmph)	
	SITES IN USA							
1	I 271 South bound driving lane	Dec 21-Dec 24,04	56.7(91.4)	35.2(56.6)	62.0			24 hrs 55 min
2	I 271 South bound passing lane	Dec 22-Dec 24,04	60.9(98.0)	30.9(49.7)	50.7			12 hrs 10 min
3	I 76 West driving lane	Jan 22,05	54.8(88.1)	41.4(66.6)	75.5			8 hrs 10 mins
4	I 76 West passing lane	Jan 21-Jan 22,05	61.1(98.3)	41.7(67.1)	68.2			17 hrs 55 min
5	Dane County,Wisconson	Feb 11-Feb 12,03	60.0(96.5)	15.0(24.1)	25.0			3 hrs
	SITES IN SWIZTERLAND							
6	Wadenswil , Lane 1	Feb 4,03	68.3(110.0)	42.2(67.9)	61.8	84.5	48.4(77.8)	
7	Hunzenschwil, Lane 4	Jan 7,03	67.7(108.9)	47.8(76.9)	70.6	89.9	32.9(52.9)	
8	Mattstetten, Lane 4	Jan 27,04	67.7(108.9)	44.1(70.9)	65.1	83.5	50.9(81.9)	
9	St.Gallen,Rorschacheerstrasse, Lane 1	Jan 29,04	36.6(58.9)	26.0(41.8)	71.9	96.6	34.1(54.8)	
10	Zurich,Rosengartenstr, Lane 4	Feb 06,04	29.8(47.9)	25.4(40.8)	85.4	95.8	28.5(45.8)	
			Sites 1-8	Sites 1-8	Sites 1-8	Sites 6-8	Sites 6-8	
			mph(kmph)	mph(kmph)	%	%	mph(kmph)	
		Average	62.1(99.9)	37.3(60.0)	59.9	86.0	44.0(70.8)	
		Standard deviation	5.2(8.3)	10.4(16.7)	15.9	3.4	9.7(15.6)	

Note:1) Winter storm-Situation in which road is assumed to be covered by snow
2) Sites 9 and 10 are streets with in the city

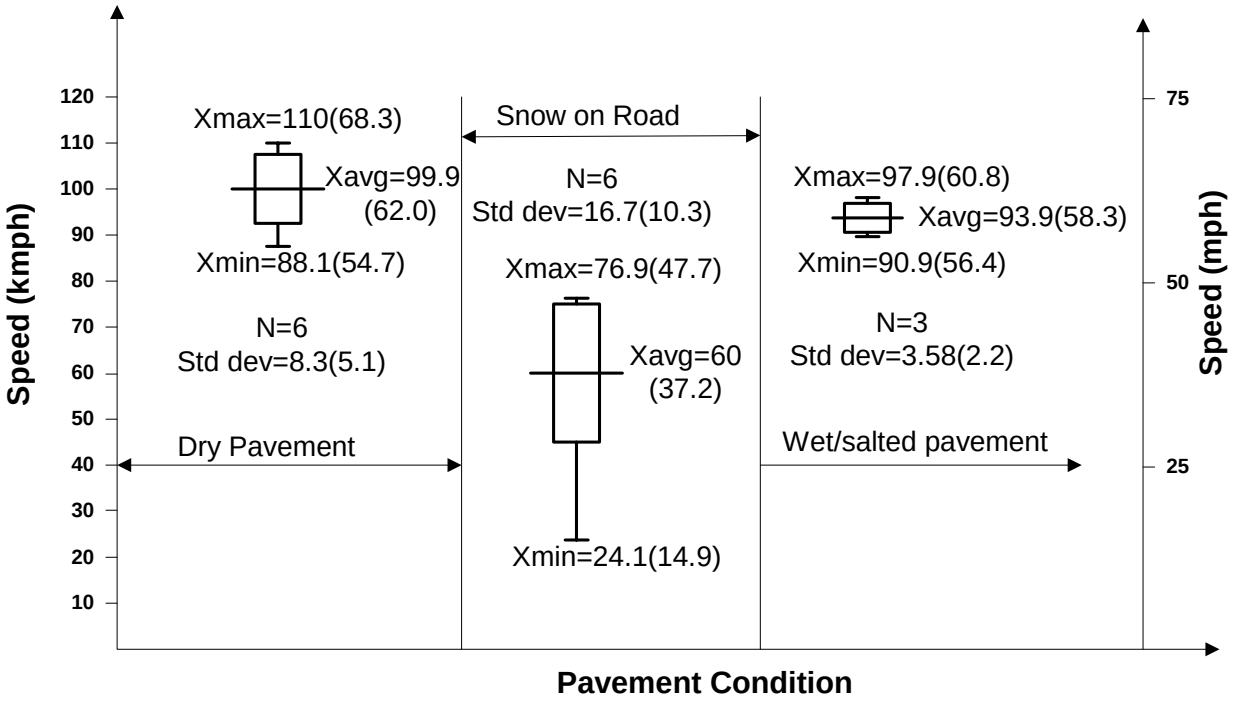

Figure 131: Graph showing the maximum, minimum and the average speeds obtained for freeway sites tabulated in Table 99.All the values are in kmph (mph).

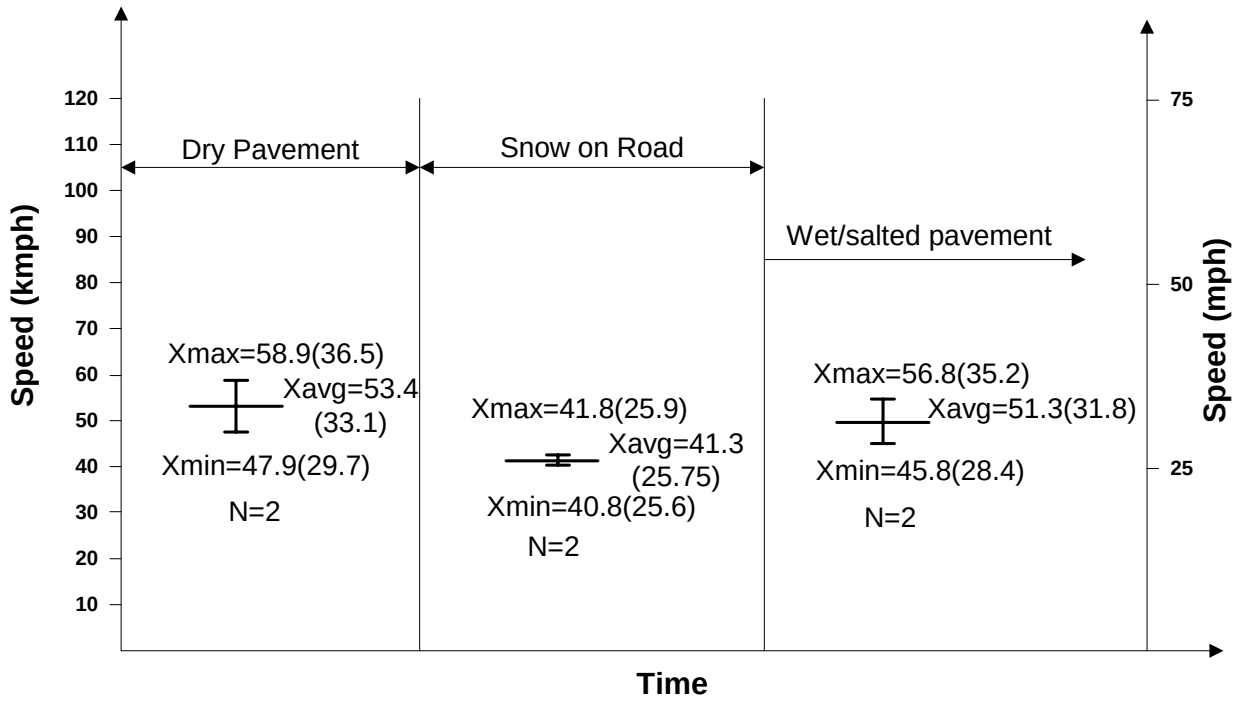

Figure 132: Graph showing the maximum, minimum and average speeds obtained for city streets tabulated in Table 99.All the values are in kmph (mph).

Figure 131 and Figure 132 show the minimum, maximum and the average speeds obtained for the freeways and city streets respectively. It can be seen from Figure 132 that with snow on the road, the speed goes down to an average from 62 mph (99.77 kmph) to 37.2 mph (59.86 kmph). The speed increases to 58.3 mph (93.82 kmph) after the snow is cleared from the pavement and salt is applied to it.

Figure 133 and Figure 134 show the distribution of velocity in Wadenswil. Switzerland on the 4th February 2003 at 6:30 am to 7:30 am in lane1 and St.Gallen Rorschacherstrasse, Switzerland on the 7th January 2003 from 7:45 pm-8:45 pm. It can be seen from the graphs that the median speeds increase by 34kmph (21.10 mph) on freeways and13 kmph (8.10 mph) on city streets after one hour of the winter storm.

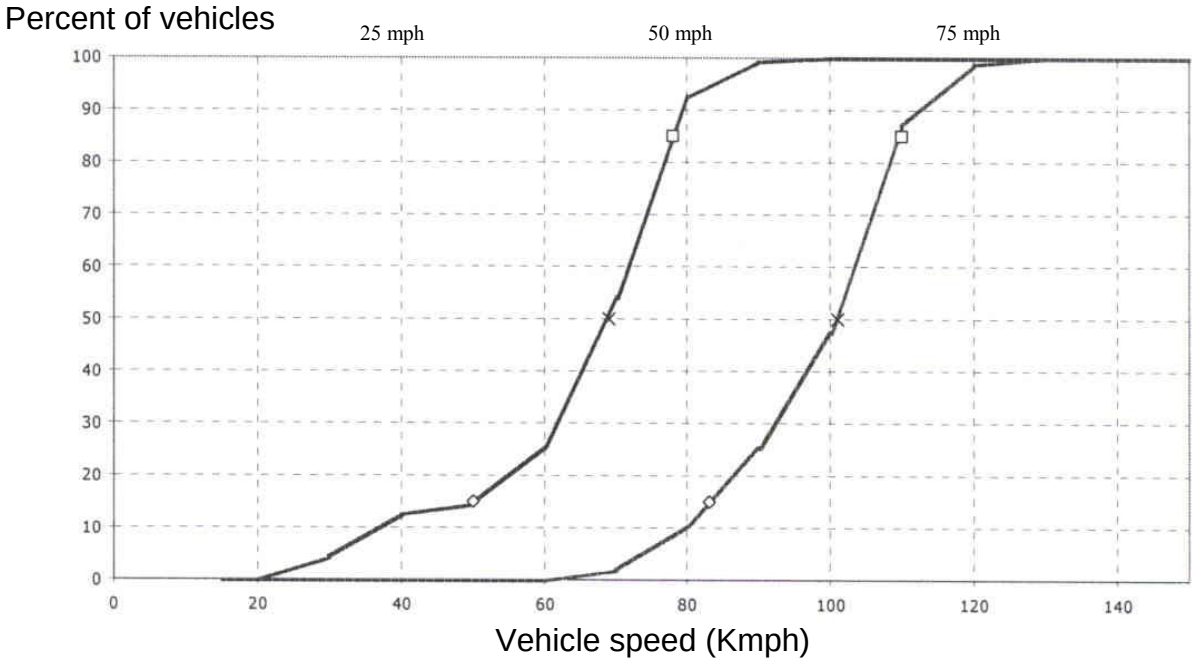

Figure 133: Distribution of velocity in Wadenswil, Switzerland on 4th February, 2003 at 6:30 AM and 7:30 AM in Lane1 [2].

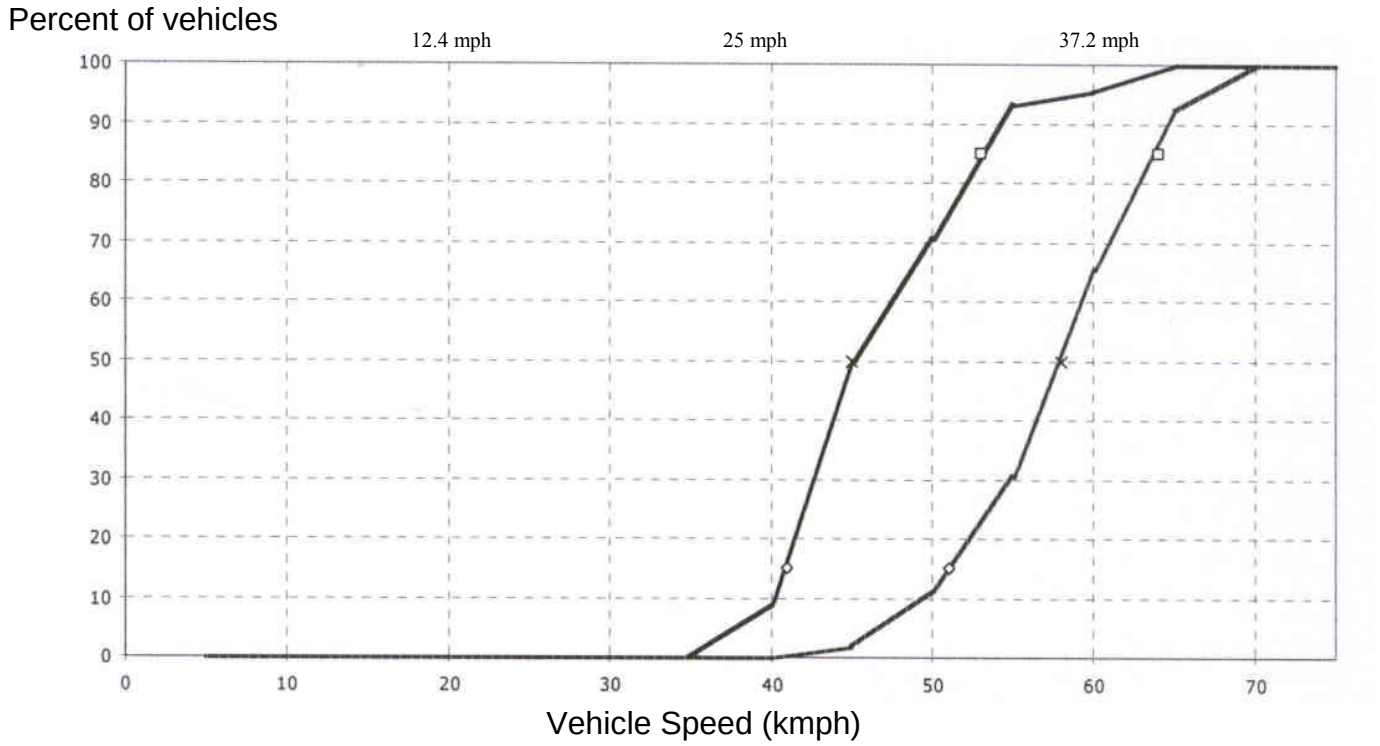

Figure 134: Distribution of velocity in St Gallen, Rorschacherstrasse, Switzerland on 7th January, 2003 at 7:45 PM and 8:45 PM in Lane 1[2].

Figure 135 and Figure 136 shows the vehicle speed and traffic volume plot at Hunzenschwil, Switzerland with dry pavement condition on 17th March 2004 and during a winter storm on January 29 2004. Figure 135 show that all the vehicles were traveling at 100-120 kmph (62.13-74.56 mph) where as during a winter storm the speeds are dispersed because of the snow clearing and salting on the pavement.

Figure 137 and Figure 138 show the distribution of traffic volumes and speeds for 15 minute intervals at Wadenswil, Switzerland on 4th February, 2003 in lane 1 and at St Gallen, Rorschacherstrasse, Switzerland on 7th January, 2004 in lane 1.The black and grey lines show traffic volume and traffic speeds respectively.

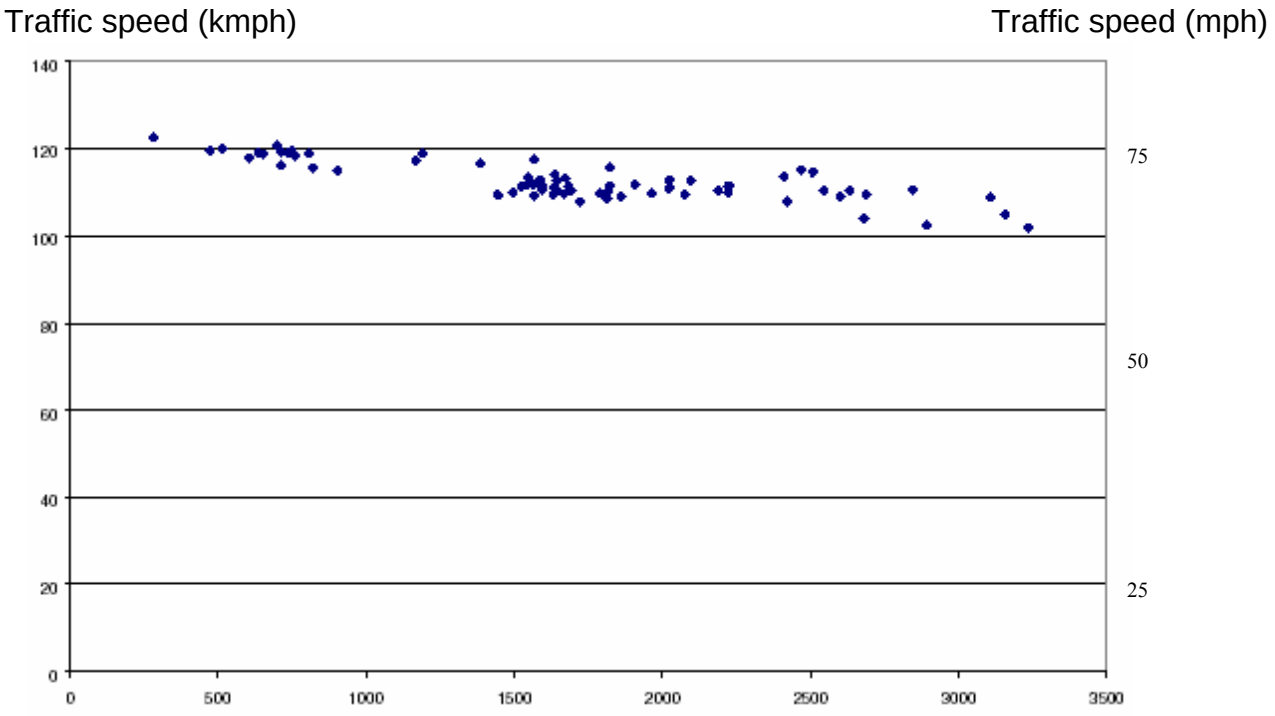

Figure 135: Graph showing vehicle speed and traffic volumes with dry pavement condition at Hunzenschwil, Switzerland on 17th March, 2004[2].

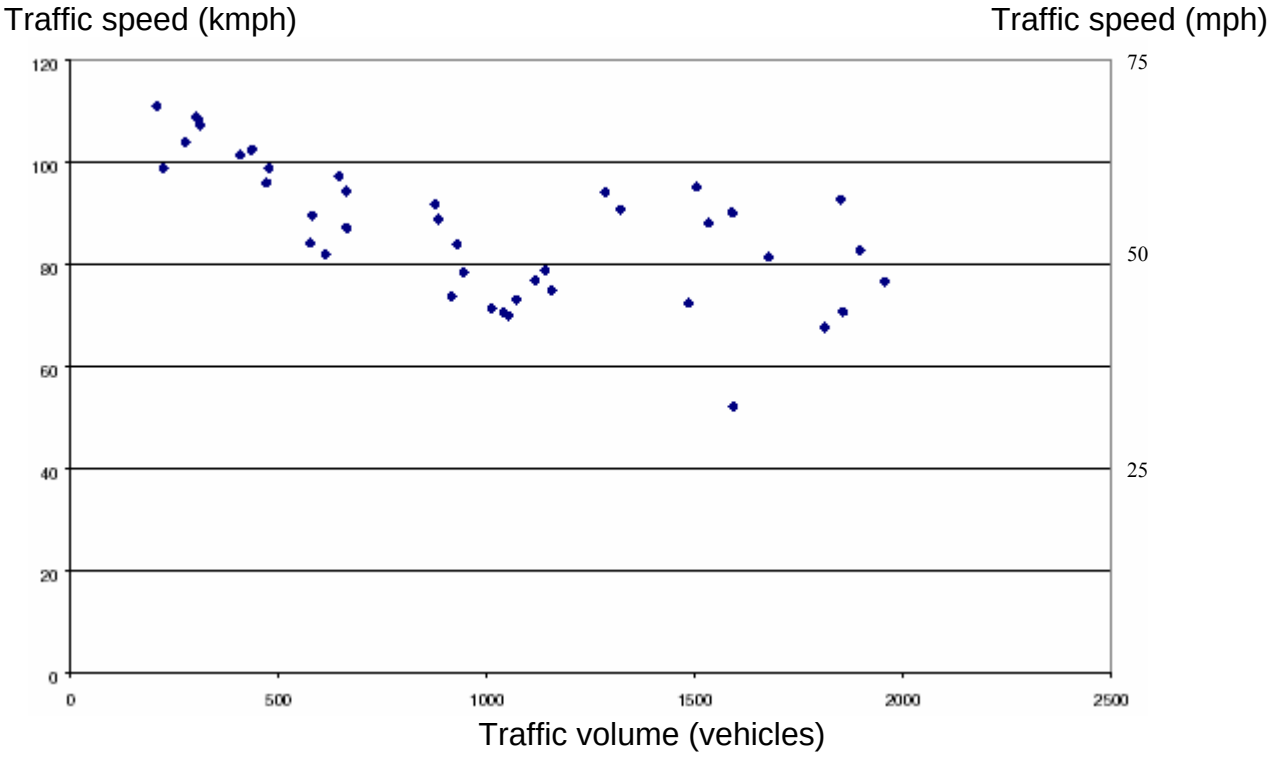

Figure 136: Graph showing vehicle speed and traffic volumes during a winter storm at Hunzenschwil, Switzerland on January 29, 2004[2].

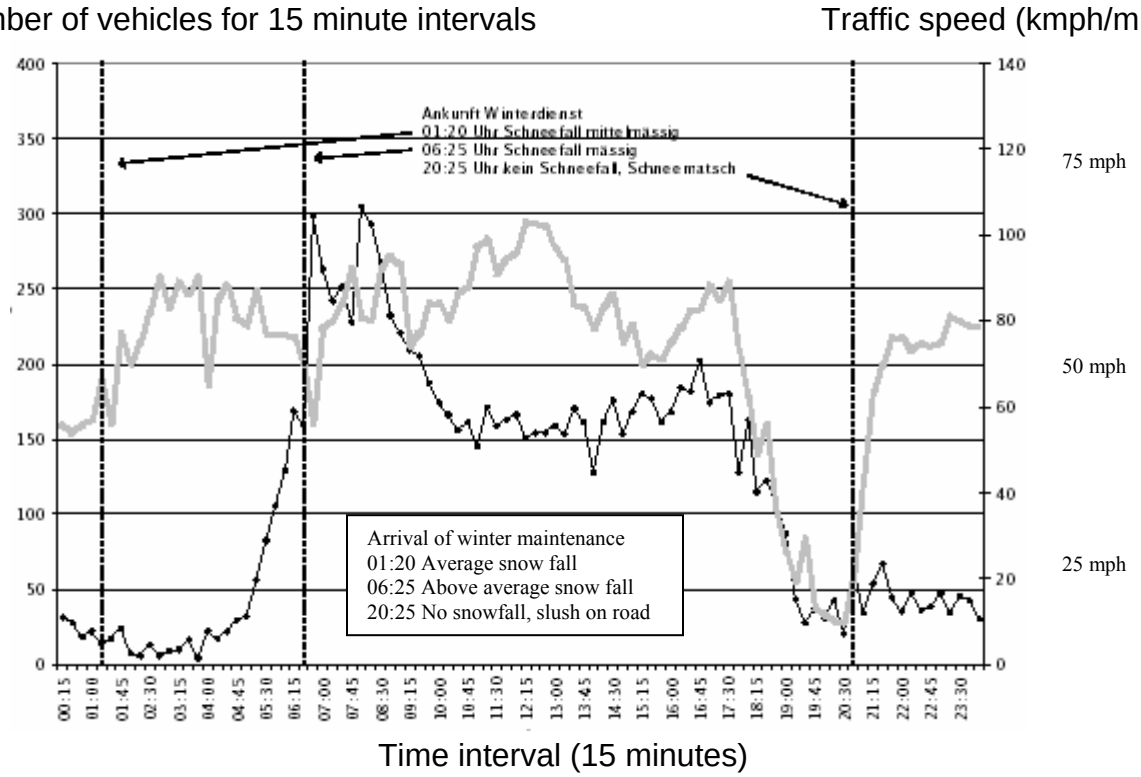

Figure 137: Graph showing the speeds and traffic volumes at Wadenswil, Switzerland on 4th February, 2003 in lane 1[2] for 15 minute intervals.

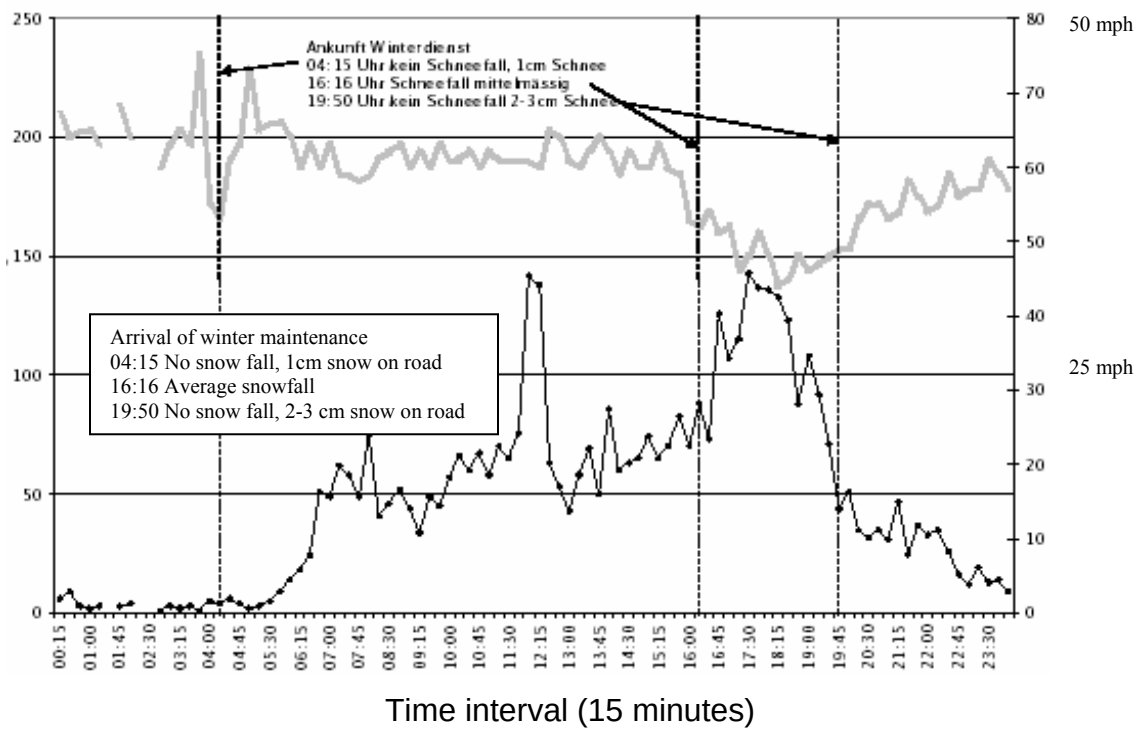

Figure 138: Graph showing the speeds and traffic volumes at St Gallen, Rorschacherstrasse, Switzerland on 7th January, 2004 in lane 1[2] for 15 minute intervals.

13. CONCLUSIONS AND RECOMMENDATIONS TO DETERMINE THE LEVEL OF SERVICE:

As mentioned earlier in the report due to the lack of winter storms in the Cleveland\Akron area during the 2004, 2005 and 2006 years, the findings of the study are somewhat limited and based on a small sample of winter conditions. Therefore the recommendations proposed must be considered as fairly general and are also based on the results from a recent study conducted in Switzerland. The same applies to the results of the driver surveys which appear to be somewhat biased and conducted during rather severe winter conditions (large amount of snowfall over an extended period of time) and statements regarding the level of service provided only reflect a small sample of the actual winter conditions. They appear to be somewhat biased towards the most severe winter storm conditions.

In the study, it was found that the average traffic speeds were significantly lower during a snow event even when periodic plowing and salting was done. The speeds decreased linearly for the period of the snow storm, reached the minimum and then climbed back to higher speeds. The speeds appear to be a fairly sensitive measure to judge the condition of the pavement. The motorist judgments about the pavement condition and their perception of the safety of driving decreases which is mirrored in the speed decrease. It appears from the survey about two thirds of the motorists judge the detoriation of the road conditions and inadequate level of road maintenance as bad or moderately bad. The responses obtained for the car and truck drivers are fairly close to each other indicating that both groups can judge bad road and maintenance conditions. The observed road conditions appear to influence the drivers in terms of how they subjectively feel about reduced the level of safety and increased level of stress experienced during driving.

In the study it was found that road surface condition, traffic volume density, visibility, amount of snowfall, storm duration and air temperature are the major factors that affect the driving/traffic speeds. A simple procedure was developed for winter maintenance management to determine the condition of the road (freeways) based on the average speeds observed by RWIS sensors. If the average winter speed of the traffic is equal or greater than the historical established wet/salted pavement speed, the level of service is considered adequate. According to the Swiss report the wet/salted surface winter speeds is about 85% of the dry surface speed. If the average winter speed is below the wet/salted surface speed, the level of service is considered inadequate. Any speed less than 50% of the wet/salted surface speed indicates fairly bad road conditions and a highly inadequate level of service. It should be noted that the winter pavement conditions can be highly dynamic. Depending on the rate of accumulation of snow, frequency of the snow plow, length of the snow plow route the pavement condition can improve or detoriate a number of times during a winter storm. The level of service can get worse even with maximum snow plowing and salting in a situation with high rate of accumulation of snow. As mentioned above, winter pavement conditions can be highly dynamic therefore the winter driving speeds can be highly dynamic too. Even under optimal plowing and salting conditions, the driving speeds can be such that for a certain period of time an inadequate level of service can be observed under heavy snowfall. The key in such a situation would be how quickly the level of service can be improved to become adequate and the speed recovery duration as discussed in [1] could serve as an additional indicator of the level of winter maintenance.

Based on the RWIS average speeds and the driver surveys we conclude that most drivers are capable of perceiving dangerous, bad road conditions during a winter storm and most of them will lower their speeds to maintain an acceptable level of safety. Therefore the use of the current average speeds appears to be a fairly good tool to determine the level of service. In addition

having the average RWIS speeds available on a near real time basis enables winter operations managers to adjust their assignments of resources in a more optimal manner while the winter storm is in progress.

The wet/salted road speeds given by the RWIS sensors can be used to define the level of service. The speeds obtained can be adjusted for daylight and night time. If during a winter storm, the observed speeds (given by RWIS sensors) are equal or greater than the winter speeds for wet and salted pavements condition, the level of service can be assumed to be adequate. Recommendations are developed to determine the level of snow and ice control operations based on the percentage ranges of the dry surface, snow free winter average speeds. Table 100 shows the recommended percentage ranges of the average dry pavement surface winter speeds to determine the level of snow and ice control operations. The percentage ranges of the average dry pavement surface speeds are arbitrarily divided so that they roughly result in the same number of classes as used by [5], [6] assuming that the speeds decreased linearly during a snow storm. The advantages of using the average traffic speeds to determine the level of snow and ice control is that the speed measurements are almost real time (reported for every five minute interval) and the inherent variability in single speed measurements is reduced by using an average speed value. It should be noted that these recommended percentage ranges of the average dry pavement surface speed to determine the level of snow and ice control operations are not applicable to weather conditions such as dense fog where driving visibility is severely limited and the driving speeds are very low.

Table 100 . Recommended percentage ranges of the average dry pavement surface winter speeds to determine the level of snow and ice control operations.

% of dry surface winter speed	Level of snow and ice control operations
76-100%	Adequate
68-75 %	Slightly inadequate
60-67 %	Moderately inadequate
51-59 %	Inadequate
42-50 %	Highly inadequate
<41 %	Extremely inadequate

The lowest average speed percentage level for the level of "adequate" is derived by multiplying the wet/salted surface speed percentage of 90 % by 0.85 (as the average wet/salted surface speeds are about 85% of the dry pavement surface winter speeds) which results in a percentage value of about 76%. The percentage level of 90% recognizes than an average speed which is within 90% of the average wet/salted surface speed may still be considered as providing an adequate pavement conditions for driving safely considering the high cost of snow removal, salting operations and the environmental impact of salt.

14. LIST OF REFERENCES

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