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GASOLINE CONSUMPTION BY SNOWMOBILES WITHIN MINNESOTA

FINAL REPORT TO:

Minnesota Department of Natural Resources
Trails and Waterways Unit

Submitted by

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University of Minnesota
Department of Forest Resources
1530 North Cleveland Avenue
St. Paul, MN 55108

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Consultant's Report prepared for the Department of Natural Resources

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Gasoline Consumption By Snowmobiles Within Minnesota

EXECUTIVE SUMMARY

Minnesota is a snowmobiling state. 191,715 snowmobiles were registered within the state as of June, 1990, representing the third straight year of increased registration numbers of snowmobiles. Nearly twenty-one percent (650,000) of all Minnesotans over the age of eighteen reportedly snowmobile at least once each winter. Owners of snowmobiles average 19.5 days of snowmobiling and spend an average of $29.50 per person per day of snowmobiling. Expenditures by snowmobile owners and riders accounts for a significant proportion of the state's winter tourism revenues. In support of this activity, the state enjoys more than 12,500 miles of snowmobile trails.

Participation rates for snowmobiling can change over time. This requires a periodic reassessment of the assumptions and calculations used to establish the gasoline tax allocation formulas. This paper reports estimated gasoline consumption over the past 6 seasons based on existing data and data collected over the last three months about snowmobile use. Furthermore, the paper reports development of a Winter Algorithm that predicts future gasoline consumption by snowmobiles within Minnesota. Study results should help to determine "...the appropriateness of the present formula dedicating a share of the unrefunded gas tax to the snowmobile account." (Laws of MN, 1991, Chap. 254, Article 1, Subd. 6).

A postcard survey of registered Minnesota snowmobile owners was performed during the months of November and December, 1991. This survey provided data on fuel efficiency, total miles traveled, number of days on Minnesota trails and non-Minnesota trails, and average number of miles per day while traveling on trails. Data from this survey was used to determine the total gasoline consumption by snowmobiles within Minnesota for the 1990/1991 use season.

Fuel efficiency for snowmobiles ranged from 4 to 25 miles per gallon. The average fuel efficiency of snowmobiles is 13.7 miles per gallon, a figure supported by both the survey and industry professionals.

There are roughly the same number of registered vehicles in Minnesota as there are registered vehicles in the four surrounding states. The Minnesota Department of Natural Resources estimates that there is, at the minimum, no net loss of snowmobile use from Minnesota to the surrounding states when compared to the incoming use of Minnesota snowmobiling resources by nonMinnesotans. Therefore, the 1990/1991 season's minimum gasoline consumption by nonMinnesota snowmobiles within Minnesota is 1,821,292 gallons.

The Average Winter Algorithm developed by this study is based upon a strong linear association between late January snow depth in the Grand Marais area and the gasoline consumed per vehicle. The algorithm was derived from six past snowmobile use seasons using correlation and regression analysis. The algorithm provides an equation for predicting gasoline consumption per vehicle on Minnesota trails for any given season based on the January 25th snow depth in the Grand Marais area. The equation is:

$$G.C.P.V. = 15.5047 + (.8482 * GMsnow)$$

Where G.C.P.V. = predicted gasoline consumption per vehicle; and
GMsnow = January 25th snow depth in the Grand Marais area.

To insure the long term validity of the Winter Algorithm as a prediction tool, at least four more seasons of snowmobile use data must be collected.

Results from the survey indicated that there was an average of 1.5 gallons of gasoline consumed per vehicle in Minnesota excluding gasoline consumed while riding on trails. This nontrail consumption figure was adjusted to reflect nontrail recreation-only consumption. The nontrail recreational consumption per vehicle was 1.026 gallons of gasoline per vehicle.

The minimum gallons of gasoline consumed for recreational purposes is based upon registered snowmobiles only; the maximum gallons is based upon the number of registered and the maximum estimate for nonregistered snowmobiles. We assume that use levels are identical between registered and nonregistered snowmobiles.

For the 1990/1991 use season, the total recreational gasoline consumption by all snowmobiles within Minnesota ranges from a minimum of 9,648,249 gallons to a maximum of 12,387,673 gallons.

For the 1991/1992 use season, the total recreational gasoline consumption by all snowmobiles within Minnesota ranges from a minimum of 7,754,871 gallons to a maximum of 9,831,616 gallons.

For the average winter use season, the total recreational gasoline consumption by all snowmobiles within Minnesota ranges from a minimum of 7,429,723 gallons to a maximum of 9,392,666 gallons.

Gasoline Consumption By Snowmobiles Within Minnesota

INTRODUCTION

Minnesota is a snowmobiling state. 191,715 snowmobiles were registered within the state as of June, 1990, representing the third straight year of increased registration numbers of snowmobiles. Nearly twenty-one percent (650,000) of all Minnesotans over the age of eighteen reportedly snowmobile at least once each winter. Owners of snowmobiles average 19.5 days of snowmobiling and spend an average of $29.50 per person per day of snowmobiling. Expenditures by snowmobile owners and riders accounts for a significant proportion of the state's winter tourism revenues. In support of this activity, the state enjoys more than 12,500 miles of snowmobile trails.

Snowmobile facilities are provided primarily through two legislatively authorized funding mechanisms: snowmobile registration fees ($30 for three years), and "unrefunded gasoline tax" receipts attributed to nonhighway snowmobile use. The "unrefunded gasoline tax" is collected on all gasoline sold within Minnesota. The vast majority of these revenues support the state's road system, but certain activities have been legislatively permitted to make a "claim" on these revenues consistent with the amount of gasoline that these activities consume without using Minnesota's roads. Snowmobile use is included in this category. At present, the Department of Natural Resources receives annually three-quarters of one percent of the state's gasoline tax receipts for operation of the program. Together registration fees and gas tax revenues annually generate over $4,500,000.

Participation rates for snowmobiling can change over time. This requires a periodic reassessment of the assumptions and calculations used to establish the gasoline tax allocation formulas. This paper reports estimated gasoline consumption over the past 6 seasons based on existing data and data collected over the last three months about snowmobile use. Study results should help to determine "...the appropriateness of the present formula dedicating a share of the unrefunded gas tax to the snowmobile account." (Laws of MN, 1991, Chap. 254, Article 1, Subd. 6).

STUDY GOALS

Our goals were to:

1. develop a Minnesota snowmobile gasoline consumption model that provides estimates of the total amount of gasoline consumed by Minnesota snowmobiles during an "average" winter.

2. determine the total amount of gasoline consumed by snowmobiles within Minnesota during the 1990-1991 use season.

To achieve these goals we:

a. defined an "average snowmobiling" winter in Minnesota and developed an "average snowmobiling winter" algorithm for use in predicting use levels for any given winter;

b. identified and assessed past Minnesota snowmobile trail use data;

c. identified the fuel efficiency (miles-per-gallon) of the major snowmobile brands used in Minnesota;

d. assessed out-of-state snowmobile use of Minnesota snowmobile trails; and,

e. computed the total amount of gasoline consumed by snowmobiles within Minnesota during the 1990/1991 use season.

RESULTS

Past Snowmobile Use Data

The DNR has conducted surveys of snowmobilers within Minnesota for each of the use seasons from 1983/1984 to the present with the exception of the 1987/1988 use season. Data from each of these use seasons was collected either through the mail or by phone.

The purpose of this study was not to assess the validity of the past data collection techniques and tools; validity is assumed. However, early survey questionnaires differ from the latter survey

questionnaires in the types of questions asked, the wording of similar questions, and the analysis of survey responses. This study required the identification of "common" data sets for each of the past use seasons. Common data sets are data that for all seasons, have a common unit of measure (i.e. miles, days) and were derived from survey questions identical or similar enough in nature from season to season. Of the six past use seasons for which data has been collected, only the 1983/1984 seasonal data did not have enough data in common with the other seasonal data sets to be of use for this study.

Table 1 examines past season trail use and gasoline consumed. Three variables: "average number of days on trails", "average miles per day on trails" and the "total number of registered snowmobiles", were used from the five use seasons that shared common data. These variables, when coupled with a standard miles-per-gallon figure (discussed later in this section), produce total gas consumption on trails for each use season. It is important to note that these figures do not include nonregistered Minnesota snowmobile use, out-of-state gasoline consumption figures, and nontrail recreational snowmobile use.

Table 1: Gas consumption for registered snowmobile use in Minnesota by Minnesotans

Year	Avg # days on trail	x	Avg mi/day trails	=	Total miles on trails	/	vehicle miles per gallon		gal/ yr	x	# regist. snowmo.	=	total gallons
84-85	3.9	x	72	=	280.8	/	13.7	=	20.5	x	203,000	=	4,161,500
85-86	5.9	x	74	=	436.6	/	13.7	=	31.9	x	181,000	=	5,773,900
86-87	3.8	x	67	=	254.6	/	13.7	=	18.6	x	170,000	=	3,162,000
88-89	12.7	x	55	=	698.5	/	13.7	=	51.0	x	184,000	=	9,384,000
89-90	8.9	x	56	=	498.4	/	13.7	=	36.4	x	184,000	=	6,697,600

Average Winter Algorithm

It is believed that there is a somewhat direct relationship between snow accumulations in late January and the total snowmobile use levels for any given season (Regnier, Present Attitudes and Long-Term Behavior of Minnesota Snowmobilers, MN DNR, 1988). To examine this hypothesis, data on past snowmobile use levels and the late January snow depth at sites representative of typical Minnesota snowmobiling regions were collected. The data were subjected to analysis through the use of correlation analysis, simple linear regression (least squares analysis), and stepwise regression. Correlation and regression analysis provided the means to develop a Winter Algorithm that

estimates total gas consumption by registered snowmobiles for any given season. To assess this predictive model, all major assumptions were independently tested and the 1990/1991 total gasoline consumption figures were compared to the predicted gasoline consumption figure derived from the Winter Algorithm.

To test the hypothesis that snow depth influences snowmobile use levels, two sets of data had to be identified. The first set of data is January 25th snow depth data. The second set of data is the snowmobile seasonal use level data. Snowmobile use cannot affect the amount of snow that has fallen, therefore, snow depth data can be thought of as being "independent" from snowmobile use level data. Conversely, snowmobile seasonal use level data can be thought of as being "dependent" to some degree on the snow depth. An inherent relationship between snow depth and snowmobile use is known to exist at the most basic level: the ability to snowmobile is dependent upon the existence of some snow cover. Beyond this simple relationship, statistical analysis helps us identify and define the relationships that exist between snow depth and use levels.

January snow depth data were collected for each winter from 1983 to the present. Late January snow depths for three locations were chosen for analysis: the Grand Marais/Gunflint Trail area, the Brainerd area, and the Minneapolis/St. Paul (Twin Cities) metro area (Table 2). These areas contain the majority of registered snowmobiles and experience the majority of snowmobile use within Minnesota. January 25th was chosen as the date to represent late January. For each area under study, actual snow depth figures for January 25th were collected by official National Weather Service Cooperative Operators. Site specific snow depth data records are compiled by the National Climatic Data Center. For this study, the Minnesota Department of Natural Resources State Climatology office provided current and past years' January 25th snow depth data and the long term January 25th snow depth averages.

Table 2: January 25th snow depth

	January 25th snow depth			
Use Season	Grand Marais area	Brainerd area	Twin Cities area	Average of the three areas
'84/'85	4	5	7	5.3
'85/'86	18	15	13	15.3
'86/'87	15	8	1	8.0
'88/'89	43	19	1	21.0
'89/'90	18	4	0	7.3

Gas consumed per vehicle, total gas consumed by all vehicles as well as snowmobile seasonal use levels are noted in Table 1. Correlation and regression analysis require complete sets of data when dealing with small numbers of cases. Since use level information does not exist for the 1983/1984 and the 1987/1988 seasons, only use level and snow depth information for the seasons noted in Table 2 and Table 3 were used in the analysis. These figures constituted the basic dependent and independent variables for our study. The raw data used in the analysis and creation of the Winter Algorithm are displayed in Table 3.

Table 3: Data used to create the Winter Algorithm

	Dependent Variables: Gasoline consumed		**Independent Variables:** January 25th snow depth (in inches)			
Use season	per vehicle (in gallons)	by all vehicles (in millions of gallons)	Grand Marais area	Brainerd area	Twin Cities area	Average of the three areas
'84/'85	20.5	4.1615	4	5	7	5.3
'85/'86	31.9	5.7739	18	15	13	15.3
'86/'87	18.6	3.1620	15	8	1	8.0
'88/'89	51.0	9.3840	43	19	1	21.0
'89/'90	36.4	6.6976	18	4	0	7.3

Correlation Analysis

Correlation analysis examines the degree of linear association that exists between two variables. The correlation coefficient measures the strength of association between the dependent and the independent variables. The correlation coefficient ranges from 1 to -1, with 1 representing a perfect positive linear association between the variables , 0 representing no association between the variables, and -1 representing a perfect negative association between the variables. While correlation in itself does not build predictive models, it is a helpful tool in identifying strong associations between dependent and independent variables. Once these associations have been identified, regression analysis can further the development of the predictive model.

Table 4 represents the correlation matrix found between the two dependent variables (gas consumed per vehicle and gas consumed for all vehicles) and each of the independent variables (January 25th snow depths for the Grand Marais area, the Brainerd area, the Twin Cities area, and the average of the three areas).

Table 4: Correlation matrix

	January 25th snow depth			
	Grand Marais area	Brainerd area	Twin Cities area	Average of the three areas
Gas consumed by all vehicles	.8711	.6370	-.2175	.7819
Gas consumed per vehicle	.9028	.6654	-.2369	.8089

As can be seen in Table 4, the strongest association exists between gasoline consumed per vehicle and the January 25th snow depth in the Grand Marais area. Given the strength of the correlation, we plotted the association (Figure 1). The plot allows us a rough look at how well the data fit the equation. The plot shows a rough positive linear association between the two variables.

To try to achieve linearity, transformation of the dependent variables can be pursued. This transformation is done using the log of X, the square root of X, or -1/X (with X representing the dependent variable). This transformation does not change the actual association between the independent variable and the dependent variable, but provides a method for removing curvature from the linear association between the variables.

For this study, the log, square root, and -1/X of each of the dependent variables were tested against each of the independent variables. The resulting coefficient matrix can be found in Table 5. Plots of each transformed variable were examined against the original plot to determine whether the transformation had produced a"stronger" linear relationship. This examination, coupled with lower correlation coefficients for the transformed data, indicates that transformation does not improve the linear association between any of variables that already have a strong linear association.

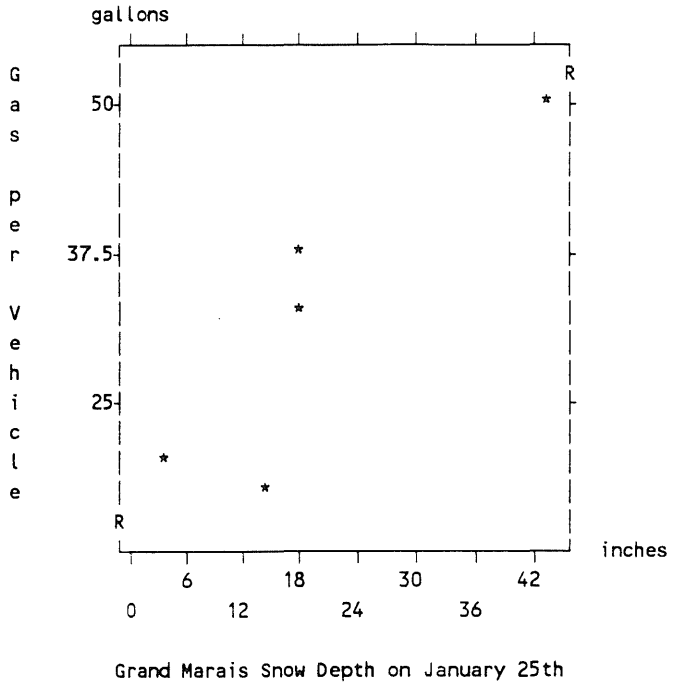

Figure 1: plot of gas consumed per vehicle with the January 25th snow depth in the Grand Marais Area

Table 5: Transformed data correlation matrix

Dependent variables & transformations	Independent variables: January 25th snow depth			
	Grand Marais area	Brainerd area	Twin cities area	Average of the three areas
Gas consumed by all vehicles (G.C.A.V.)	.8711	.6370	-.2175	.7819
Gas consumed per vehicle (G.C.P.V.)	.9028	.6654	-.2369	.8089
Log of G.C.A.V.	.7889	.5794	-.1185	.7311
Log of G.C.P.V.	.8453	.6238	-.1612	.7747
Square root of G.C.A.V.	.8337	.6100	-.1703	.7591
Square root of G.C.P.V.	.8764	.6456	-.2004	.7934
-1/G.C.A.V.	.6853	.5120	-.0108	.6639
-1/G.C.P.V.	.7760	.5782	-.0810	.7319

Correlation analysis indicated that the dependent variable, gas consumed per vehicle, had a linear association with the snow depth in the Grand Marais area, the Brainerd area, and the averaged snow depth across the three areas. These associations can be further tested through regression analysis to develop a predictive model of gasoline consumption per vehicle.

Regression Analysis

Multiple regression analysis is a statistical technique used to analyze the relationship between a single dependent variable (gas consumed per vehicle) and several independent variables (January 25th snow depths for the Grand Marais area, the Brainerd area, and the average of the three areas). SPSSpc, a statistical software package, was used to provide the regression analysis for this portion of the study. Stepwise analysis was initially used to determine the "best" possible predictive formula. Stepwise regression takes the dependent variable and compares it with each of the independent variables. The independent variable with the strongest association between it and the dependent variable becomes the first variable in the prediction equation. This is known as Step 1. Step 2 examines the association between the Step 1 equation and the other independent variables. The strongest association that exists is then incorporated into the equation. This step construction of a predictive formula continues until either all variables are incorporated into the formula or until no more associations satisfy the minimum tolerance and error criteria.

The stepwise analysis of the study data indicated that only one association fulfilled the statistical requirements of regression analysis. This association was between gasoline consumed per vehicle and the January 25th snow depth in the Grand Marais area. Stepwise analysis of two variables, one dependent and one independent, is the same as simple regression analysis. The equation for simple regression analysis is as follows:

Equation 1: Simple regression analysis equation

Given:	X	= independent variable
	Y	= dependent variable
	n	= number of cases
	sumY	= sum of all Y
	meanY	= sum of all Y / n
	sumYY	= sum of each (Y*Y)
	sumX	= sum of all X
	meanX	= sum of all X / n
	sumXX	= sum of each (X*X)
	sumXY	= sum of each (X*Y)

SigmaYY = sumYY - ((sumY*sumY)/n)
SigmaXX = sumXX - ((sumX*sumX)/n)
SigmaXY = sumXY - ((sumY*sumX)/n)

b = SigmaXY/SigmaXX
a = meanY -(b*meanX)

$$Y' = a + bX$$

Where Y' = predicted scores of the dependent variable; X = scores of the independent variable; a = intercept constant; and b = regression coefficient.

Using this equation and the identified dependent and independent variables, the Winter Algorithm equation was built:

Equation 2: Winter Algorithm equation

$$G.C.P.V. = 15.40039 + (.83059 * GMsnow)$$

Where G.C.P.V. = predicted gasoline consumption per vehicle; and
GMsnow = January 25th snow depth in the Grand Marais area.

Tests of the Winter Algorithm

Residual analysis tests, linearity tests, equality of variance tests, and independence of error tests were all performed for the Winter Algorithm. These tests produced no violations of the assumptions involved in building the algorithm. Statistically, the equation is acceptable.

The 1990/1991 January 25th snow depth in the Grand Marais area was 26 inches. Using the Winter Algorithm, the gas consumption per vehicle can be determined.

1990/1991 gas-per-vehicle = 15.40039 + (.83059*26)
= 36.996 gallons per vehicle

Gasoline consumed per vehicle during the 1990/1991 season was determined using data from the 1990/1991 Snowmobile Use Survey. Considering that the Winter Algorithm is based on data that represent the average number of days on trails and the average number of miles snowmobiled per day, the comparison between the predicted and the actual gallons of gas consumed per vehicle should be determined using the 1990/1991 average trail days and miles. That figure is 39.8 gallons consumed per vehicle. The resulting difference is an underestimation of 2.8 gallons per vehicle (an error of 7 percent). Over time, the error produced by the Winter Algorithm should negate itself.

Updating the Winter Algorithm

The Winter Algorithm, as defined in Equation 2, reflects data collected over five previous use seasons. The 1990/1991 Snowmobile Use Survey provides new data with regard to gas consumption per vehicle and snow depth in the Grand Marais area. The Winter Algorithm was computed again, based on the addition of the 1990/1991 data to the original data set (Table 3). With the addition of the 1990/1991 use season data, the correlation coefficient between the January 25th snow depth in the Grand Marais area and the gasoline consumed per vehicle is .9057, significant to the .01 level. This implies a very strong association between the two variables. When using the new data in regression analysis, the Winter Algorithm is transformed (Equation 3).

Equation 3: Winter Algorithm equation updated to reflect the addition of the 1990/1991 use season data

$$G.C.P.V. = 15.5047 + (.8482 * GMsnow)$$

Where G.C.P.V. = predicted gasoline consumption per vehicle; and
GMsnow = January 25th snow depth in the Grand Marais area.

Using the updated Winter Algorithm, the predicted gas consumption per vehicle for the 1990/1991 use season was 37.56 gallons (a prediction error of 5.6 percent).

Confidence Intervals

Using the updated Winter Algorithm, for any given year the minimum and maximum actual (versus predicted) gasoline consumption can be determined at the 95 percent confidence level using

Equation 4. Due to the small number of years for which data was available, the current Confidence Interval is large, ranging from 23.2 gallons to 51.9 gallons consumed per vehicle given a 26 inch snow depth. As new data is added to update the Winter Algorithm, the 95 percent Confidence Interval will decrease.

Equation 4: 95% Confidence Interval

95% Confidence Interval = Total Gas Consumption $\pm$ (# of snowmobiles * .5511 * GMsnow)

Where GMsnow = January 25th snow depth in the Grand Marais area.

Winter Algorithm Limitations:

The primary limitation is the minimal number of years used to generate the algorithm. Ideally, data collection on snowmobile use levels will continue for at least four years. Each year, as data is collected, the Winter Algorithm can be reworked so as to reflect the new data. Within five years, the validity of the algorithm as a tool for determining gasoline consumption by snowmobiles should be established.

The algorithm is not affected by gasoline prices, snowfall in other areas of the state, snow depth throughout the season, distribution of snowmobile ownership, intervening or competing opportunities, and distance traveled-to-snow depth ratios (distance decay modeling). These are all factors that have potential influence on the degree of error produced by the algorithm.

The Winter Algorithm does not produce the total gasoline consumed within the state. This figure requires the addition of gasoline consumption by nonregistered and out-of-state snowmobilers, and by nontrail recreational snowmobile use.

Fuel Efficiency

Fuel efficiency of major snowmobile brands in Minnesota was identified through consultation with snowmobile manufacturers. Major brands and models of snowmobiles were identified from the survey. The manufactures were contacted by phone and asked to provide specific fuel efficiency (MPG) data for the snowmobiles in the survey.

Telephone calls to the manufacturers yielded mixed results and exact figures for MPG were not readily attainable for many reasons. First, some manufacturers were reluctant to let any fuel efficiency data "out" of the company. Second, these data take different forms and are not readily comparable: some data are "engine only"--where the engine is apparently run out of the snowmobile

on a test stand in a testing lab; some data are collected on complete snowmobiles in the lab--ideal "snowless" conditions; and the field test data are--as we were told--unreliable because the snowmobiles are tested under different snow conditions by different riders. Though this third testing method may seem most plausible for the study, most manufacturers did not report having this kind of information. They stress that the actual milage that a snowmobiler gets depends on the machine is driven.

Consultation with manufacturer representatives and the "Minnesota United Snowmobilers Association" (MUSA) produced additional data. The association members said that most older snowmobiles get about 10 MPG while the newer ones get about 15 MPG. This compared well with the representative's estimates for their new snowmobiles at 8 MPG for high performance snowmobiles to the "low 20's" in MPG for their higher economy models. The "fleet" average for new snowmobiles being reported by one manufacture representative was about 15 MPG.

Respondents to the 1990-1991 Minnesota Snowmobile Survey were asked to estimate their machine's fuel efficiency. Responses ranged from 4 to 25 miles-per-gallon excluding obvious outliers. the mean fuel efficiency was 13.7 miles-per-gallon. This figure is supported by both industry and MUSA estimates and was chosen to be the standard fuel efficiency figure for computing gasoline consumption for past use seasons.

Registration information that accompanied each survey indicated the make, model, and year of the vehicle (i.e. a 1988 Polaris Exciter). An examination of fuel efficiency over the past 8 years was performed. Standard fuel efficiency for each season was determined by examining cases where the vehicle was in existence for that season (i.e. the 1985/1986 season included all cases where the vehicle model year was 1986 or earlier). The examination produced results ranging from 13.6 - 13.9 miles-per-gallon averages, with no discernable trends towards increased fuel efficiency in more recent use seasons.

Out-of-State Snowmobile Use

Surrounding States:

Out-of-state snowmobile organizations based in Wisconsin, Iowa, South Dakota, and North Dakota were identified and contacted. Larry Freidig of the Wisconsin DNR said that Wisconsin has about 150,000-155,000 registered snowmobiles. He had no idea how many people from Wisconsin used their snowmobiles in Minnesota. He "guessed" that people from Wisconsin snowmobiling in Minnesota probably consume about 200,000 gallons of gas in Minnesota. He said that the WDNR uses an empirical number (.4) to estimate gas use by people using snowmobiles in Wisconsin from

other states. Freidig referred us to the AWSC president (the Wisconsin Snowmobiling Association) who said that a lot of snowmobiling takes place between Minnesota and Wisconsin, but that it probably equals out due to the similarity of the experience in both states. He also said that he liked the empirical estimate because it worked well for them. His reason for saying that it worked well was primarily that it provided them with enough money.

In 1990, the Iowa DNR said they had 22,020 registered snowmobiles but had no idea how many were used in Minnesota. Dale Vagts, ISSA president in Iowa, said that snowmobiling in Iowa is really confined to the upper two-thirds of Iowa. Although he had no hard data to support his figures, Vagts estimated that 4,000-5,000 Iowans per year snowmobile in Minnesota and they snowmobile about 5 days (in Minnesota) spending about $100 per day. They probably average a party size of about six and travel about 100 miles per day. He also stated that there is a difference in the kinds of use that Minnesota may see: day use near the border and multi-day use farther north. He said that many snowmobilers probably cross into Minnesota to use trails just over the border, and that there is considerable interest in taking snowmobiling "vacations" to more desirable places and snow conditions in northern Minnesota.

Doug Eoute, state snowmobile program coordinator for the Department of Game, Fish, and Parks in South Dakota said that South Dakota has about 7,300 registered snowmobiles. He "guessed" that people from his state made about 25,000-30,000 trips to Minnesota to snowmobile, but he had no data to support these figures. Eoute also said that South Dakota has 27 snowmobile clubs. For the most part, these clubs are concentrated on the South Dakota-Minnesota border and the South Dakota-Wyoming border. We called several of the individual club presidents. Unfortunately, we were unable to reach them.

North Dakota was difficult to analyze. We tried several times to talk to a program coordinator who might have duties similar to South Dakota, but were unable to make contact.

Based on the information we received from the surrounding four state area, we made rough guesstimates of the gas consumed by out-of-state snowmobiles in Minnesota:

Iowa:	500 miles traveled x 4,500 vehicles =
	2,250,000 miles/ 13.7 MPG = 164,234 gallons
South Dakota:	27,500 trips x 100 miles/trip =
	2,750,000 miles/ 13.7 MPG = 200,730 gallons

Wisconsin: guess = 200,000 gallons

North Dakota: guess = 150,000 gallons

If exact figures are needed, a survey of the four adjacent states needs to be done. The total size of the project is about the same as the total size of the project for the survey within Minnesota because the total number of registered snowmobiles in the adjacent states is about the same as the total number of registered snowmobiles within Minnesota.

Canada:

It is important to note that Canadian snowmobile use within Minnesota was not determined. Assuming that snow conditions in the areas of Canada that surround northern Minnesota are similar to the snow conditions found in northern Minnesota, the primary draw of Canadian snowmobilers to Minnesota lies not in the abundance of quality snowmobile experiences, but in Canada's current economic situation where a large number of Canadians are crossing the border in search of lower priced goods.

Canadian snowmobile consumption of gasoline within Minnesota can be determined through a partnership with U.S. Customs on the Minnesota/Canadian border. All Canadians entering or leaving Minnesota must stop at customs. Either a survey of those Canadians with snowmobiles or simple odometer readings both coming and going could provide accurate gasoline consumption within Minnesota for that population.

Minnesota:

The 1990-1991 Minnesota Snowmobile Survey asked respondents to indicate the number of days they spent on snowmobile trails outside of Minnesota and the average miles traveled per day on those trails. The responses indicate that total gas consumption by Minnesotans outside of the state was 1,821,292 gallons for the 1990-1991 use season.

Total out-of-state consumption estimates:

There are roughly the same number of registered vehicles in Minnesota as there are registered vehicles in the four surrounding states. The Minnesota Department of Natural Resources estimates that there is, at the minimum, no net loss of snowmobile use from Minnesota to the surrounding states when compared to the incoming use of Minnesota snowmobiling resources by

nonMinnesotans. Therefore, the 1990/1991 season's minimum gasoline consumption by nonMinnesota snowmobiles within Minnesota is 1,821,292 gallons.

1990-1991 Gasoline Consumption by Snowmobiles

A variety of methods was used for obtaining the total gas consumption for the survey population and the total population of registered Minnesota snowmobiles (Table 6). For each method and application, gas consumption is figured on a case-by-case basis. Once the gasoline consumed for each vehicle was determined, the average gasoline consumed per vehicle was determined (Table 7).

Table 6: Methods of determining 1990/1991 gasoline consumption

METHOD	EQUATION	DEFINITION
Total Consumption	TMILES/MPG	for each case, total mileage was divided by the indicated miles-per-gallon figure.
Minnesota Trail Only Consumption	$\frac{(MILEWIMN*DAYSWIMN)}{MPG}$	for each case, indicated days on Minnesota trails were multiplied by the indicated average number of miles per day on Minnesota trails and then divided by the indicated MPG figure.
Total Consumption Within Minnesota	$\frac{(TMILES-(MILEOUMN*DAYSOUMN))}{MPG}$	for each case, total miles less the outside of Minnesota mileage was computed and then divided by the indicated mpg figure.
Total Consumption by Minnesota Vehicles Outside of Minnesota	$\frac{(DAYSOUMN*MILEOUMN)}{MPG}$	for each case, indicated days on trails outside of Minnesota were multiplied by the indicated average number of miles per day on trails outside of Minnesota and then divided by the indicated MPG figure.

Where: TMILES = respondent's indicated total miles put on vehicle during the 1990/1991 use season;
MPG = respondent's indicated miles-per-gallon figure;
MILEWIMN = respondent's indicated number of days on Minnesota trails;
DAYSWIMN = respondent's indicated average number of miles per day while travelling on Minnesota trails;
MILEOUMN = respondent's indicated number of days on trails outside of Minnesota;
DAYSOUMN = respondent's indicated average number of miles per day on trails outside of Minnesota.

Table 7: 1990/1991 gasoline consumption estimates

METHOD	N	Gas per vehicle (in gallons)	X	# regis. snowmo.	+	Estimated out-of-state consumption	=	Total 1990/1991 gasoline consumption
Total Consumption	571	51.4	X	191,715	+	1,821,292 gallons	=	11,675,443 gallons
Minnesota Trail Only Consumption	549	39.8	X	191,715	+	1,821,292 gallons	=	9,451,549 gallons
Total Consumption Within Minnesota	555	41.3	X	191,715	+	1,821,292 gallons	=	9,739,122 gallons
Total Consumption by Minnesota Vehicles Outside of Minnesota	561	9.5	X	191,715	+	not applicable	=	1,821,292 gallons

Where: N = valid cases where responses necessary for calculation of values existed.

Of the above formulas, the Total Consumption Method does not account for those Minnesotans who indicated mileage that was put on their machine outside of Minnesota. While the Minnesota Trail Only Consumption Method accounts for gasoline consumption on Minnesota trails that are designated and maintained, this figure does not include recreational snowmobiling on lakes, along the roadside, or on unofficial trails. The Total Consumption Within Minnesota Method incorporates total mileage and deducts the mileage put on machines when outside of Minnesota.

Of the three methods used to determine seasonal consumption, The Total Consumption Within Minnesota method provides the most concise and accurate method of estimating total consumption for current or past use seasons. This method's estimate of gasoline consumption by registered and out-of-state snowmobiles within Minnesota for the 1990/1991 use season is 9,739,122 gallons. However, this figure does not include consumption of gasoline by nonregistered snowmobiles, nor does it exclude consumption by snowmobiles for nonrecreational purposes. To remedy these shortcomings, additional steps were taken.

The number of nonregistered vehicles within the state is unknown. Estimates of the number of nonregistered vehicles range from 5 - 35 percent of the total number of registered vehicles.

However, nonregistered snowmobile use levels may not reflect use levels of registered snowmobiles. There is no data to support or refute the hypothesis that registered and nonregistered snowmobile recreational use levels are similar. Therefore, the minimum range for total consumption is based upon registered snowmobiles only; the maximum range is based upon the maximum estimate of registered and nonregistered snowmobiles and assumes that use levels are identical between registered and nonregistered snowmobiles (Table 8).

The estimate incorporates all types of consumption, ranging from trail use to agricultural purposes. Table 7 shows that gasoline consumption on recreational trails within Minnesota averaged 39.8 gallons while total consumption within Minnesota averaged 41.3 gallons. The difference between these figures (1.5 gallons per vehicle) represents the nontrail consumption by vehicles within Minnesota. To adjust the estimate so that it does not include nonrecreational consumption, we examined the survey responses with regard to the total number of days the snowmobile was used, the total number of days the snowmobile was used for recreation within Minnesota, the total number of days on trails within Minnesota, and the total number of days on trails outside of Minnesota. Using this information, a recreation coefficient was calculated on a case-by-case basis for the 1990/1991 survey (Equation 5). The results were then averaged, producing a recreation coefficient of (.684). This coefficient represents the recreational percentage of nontrail gasoline consumption per vehicle. The recreation coefficient is multiplied by the total nontrail consumption figure to provide the recreational nontrail consumption per vehicle (1.5 gallons per vehicle * .684 = 1.026 gallons per vehicle). The total gasoline consumption formula can then be adjusted accordingly (Table 8).

Equation %: Recreation coefficient equation

1. Nontrail recreation days within Minnesota = total MN recreation days - days on Minnesota trails

2. Total days in Minnesota = total days - days on trails outside of Minnesota

3. Recreation coefficient = $\frac{\text{nontrail recreation days within Minnesota}}{\text{total days in Minnesota}}$

Table 8: Actual total recreational gasoline consumption by all snowmobiles within Minnesota for the 1990/1991 use season[1]

	# of snow-mobiles	X	trail consumption per vehicle	+	non-trail recreation consumption per vehicle	+	Est. out-of-state consumption	=	total 90/91 gasoline consumption
total registered	191,715	X	(39.8	+	1.026)	+	1,821,292	=	9,648,249
total registered + maximum non-registered	191,715 + 67,100 = 258,815	X	(39.8	+	1.026)	+	1,821,292	=	12,387,673

[1] Based upon the 1990/1991 Minnesota Snowmobile Use Survey.

Table 8 indicates that the gasoline consumed by all snowmobiles within Minnesota, excluding nonrecreational use, ranges from 9,648,249 gallons to 12,387,673 gallons, depending on the number of nonregistered snowmobiles within Minnesota.

Comparison of actual 1990/1991 total consumption and projected 1990/1991 total consumption

The figures in Table 8 are based upon actual data derived from the study's survey returns. By substituting the 39.8 gallons of gas consumed per vehicle on trails with the Winter Algorithm's estimate of gallons per vehicle based upon late January snow depth, we can examine the degree of variance of the Winter Algorithm as a predictive formula. Given that the January 25th snow depth in the Grand Marais area for the 1990/1991 use season was 26 inches, the Winter Algorithm estimates that the total gasoline consumption per vehicle on Minnesota trails is 37.56 gallons. Table 9 substitutes this figure for the actual gasoline consumed per vehicle on Minnesota trails to produce the 1990/1991 estimated total recreational consumption.

Table 9: Estimated total recreational gasoline consumption by all snowmobiles within Minnesota for the 1990/1991 use season

	# of snow-mobiles	X	trail consumption per vehicle	+	non-trail recreation consumption per vehicle	+	Est. out-of-state consumption	=	total 90/91 gasoline consumption
total registered	191,715	X	(37.56	+	1.026)	+	1,821,292	=	9,218,807 [1]
total registered + maximum non-registered	191,715 + 67,100 = 258,815	X	(37.56	+	1.026)	+	1,821,292	=	11,807,928 [2]

The 95% Confidence Interval = Total Gas Consumption $\pm$ (# of snowmobiles * .5511 * snow depth)

[1] 95% Confidence Interval = 9,218,807 $\pm$ 2,747,007.5 gallons

[2] 95% Confidence Interval = 11,807,928 $\pm$ 3,708,456.6 gallons

The estimated total gasoline consumption figures in Table 9 represent a difference of -429,442 and 579,745 gallons when compared to the actual minimum and maximum figures for that season, respectively. These amounts represent an underestimation error of approximately 4.5 percent. When using the Winter Algorithm, error between the actual and predicted consumption levels per vehicle are expected to exist for any given season and will reflect an overestimation or underestimation of total consumption for any given season. Over multiple seasons, the differences between the estimated and actual total gasoline consumption figures will negate each other, so that overestimates equal underestimates. This provides an accurate average total consumption estimate when using the Winter Algorithm.

1991/1992 Projected Total Recreational Gasoline Consumption by Snowmobiles Within Minnesota

To project total recreational gasoline consumption for the current season, the procedure for determining the estimated 1990/1991 winter total recreational gasoline consumption is followed, substituting the 1990/1991 late January snow depth figure with the 1991/1992 snow depth figure. For the 1991/1992 use season, the State Climatologist indicates that the late January snow depth in the Grand Marais area was 17 inches. Based on this snow depth figure, the Winter Algorithm estimates that the total recreational trail consumption within Minnesota is 29.924 gallons per

vehicle. Table 10 provides the estimates of total recreational gasoline consumption by snowmobiles within Minnesota for the 1991/1992 use season.

Table 10: Total recreational gasoline consumption by all snowmobiles within Minnesota for the 1991/1992 use season

	# of snow-mobiles[1]	X	trail consumption per vehicle[2]	+	non-trail recreation consumption per vehicle[3]	+	Est. out-of-state consumption[3]	=	total 90/91 gasoline consumption
total registered	191,715	X	(29.924	+	1.026)	+	1,821,292	=	7,754,871 [4]
total registered + maximum non-registered	191,715 + 67,100 = 258,815	X	(29.924	+	1.026)	+	1,821,292	=	9,831,616 [5]

[1] Based upon total registered vehicles as of July, 1991.

[2] Based on 24 inches of snow and the Winter Algorithm.

[3] Based on data from the 1990/1991 Minnesota Snowmobile Use Survey.

[4] 95% Confidence Interval = 7,754,871 $\pm$ 1,796,120 gallons

[5] 95% Confidence Interval = 9,831,616 $\pm$ 2,424,838 gallons

Estimating Total Recreational Gasoline Consumption by Snowmobiles Within Minnesota For Future Use Seasons

The Winter Algorithm provides the means to project average gasoline consumption by all snowmobiles within Minnesota, excluding nonrecreational consumption, based on the average late January snow depth in the Grand Marais area. Records held by the Minnesota Department of Natural Resource's State Climatology office indicate that the average January 25th snow depth for the Grand Marais area (from 1949 to 1992) is 15 inches. Using this figure, the Winter Algorithm computes the average gasoline consumption per vehicle on trails within Minnesota (Equation 6).

Equation 6: Average winter gasoline consumption per vehicle on Minnesota trails

$$28.228 \text{ gallons per vehicle} = 15.5047 + (.8482 * 15)$$

To further project gasoline consumption for an average winter, four assumptions must be made:

1. the number of registered vehicles remains constant at 191,715;
2. the maximum percentage of nonregistered vehicles is 35 percent of the total number of registered vehicles;
3. nontrail recreational consumption levels are the same as the current 1990/1991 rate of 1.026 gallons per vehicle; and
4. the estimated out-of-state consumption remains at the 1990/1991 use season level of 1,821,292 gallons.

Using the average winter trail consumption figure provided by Equation 5 and the assumed figures, Table 11 projects the average winter total recreational gasoline consumption by all snowmobiles within Minnesota.

Table 11: Average winter total recreational gasoline consumption by all snowmobiles within Minnesota

	# of snow-mobiles	X	trail consumption per vehicle	+	non-trail recreation consumption per vehicle	+	Est. out-of-state consumption	=	average winter total recreational gasoline consumption
total registered	191,715	X	(28.228	+	1.026)	+	1,821,292	=	7,429,723 [1]
total registered + maximum non-registered	191,715 + 67,100 = 258,815	X	(28.228	+	1.026)	+	1,821,292	=	9,392,666 [2]

[1] 95% Confidence Interval = 7,429,723 $\pm$ 1,584,812 gallons

[2] 95% Confidence Interval = 9,392,666 $\pm$ 2,139,492 gallons

For the average season:

the minimum total recreational gasoline consumption by all snowmobiles within Minnesota is 7,429,723 gallons, and

the maximum total recreational gasoline consumption by all snowmobiles within Minnesota is 9,392,666 gallons.

CONCLUSIONS

As mentioned previously, the Winter Algorithm is based on an association between the January 25th snow depth in the Grand Marais area and the gasoline consumed per vehicle on Minnesota trails. The updated Winter Algorithm equation was developed using data from six snowmobile use seasons. The validity and accuracy of the Winter Algorithm is dependent upon the continued collection of snowmobile seasonal use data. For each new season of data, the Winter Algorithm should be updated using the simple regression formula (Equation 1, example in Appendix C). After data on the next four snowmobile use seasons have been collected, the Winter Algorithm should undergo a complete reanalysis to determine if there are other associations that could be included in the equation to reduce error. Data from a minimum of ten seasons should provide a long-term equation for predicting gasoline consumption by snowmobiles within Minnesota.

The average winter total recreational consumption figures are derived, in part, from four assumptions. It is possible that the total number of registered snowmobiles will increase, as has been the trend for the past four years. Additional research could provide an accurate estimate of the number of nonregistered snowmobiles within the state and the use levels of those snowmobiles. Continued collection of information will yield insight into the use levels of nontrail recreational and nonrecreational snowmobiling. Out-of-state gasoline consumption can be adequately determined through surveys of snowmobilers from other states. With the reduction of assumptions comes increased accuracy and confidence in estimating future gasoline consumption by all snowmobiles within Minnesota.

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APPENDIX A:
1990/1991 Minnesota Snowmobile Survey Results

Description of Variables Obtained by Survey.

The following are the basic variables gathered (including the variable label used during the mathematical analysis) in the survey and a description of their meaning:

	Meaning	Label
1.	Total miles snowmobile was used in 1990-91.	TMILES
2.	Total days snowmobile was used in 1990-91.	TDAYS
3.	Total days snowmobile was used for recreation in Minnesota in 1990-91.	DAYSREC
4.	Total days snowmobile was used for ag/farming purposes in 1990-91.	DAYSFARM
5.	Total days snowmobile was used on developed trails in Minnesota in 1990-91.	DAYSWIMN
6.	Total miles traveled per day on developed trails in Minnesota in 1990-91.	MILEWIMN
7.	Total days snowmobile was used on developed trails outside of Minnesota in 1990-91.	DAYSOUMN
8.	Total miles traveled per day on developed trails outside of Minnesota in 1990-91.	MILEOUMN
9.	Estimated MPG for the snowmobile in survey.	MPG

Rejection of Outlying Data Points.

The following table describes the accepted data ranges for each basic variable and the reason why this range was chosen.

	Variable	Range	Reason
1.	TMILES	<5000	Data larger than this was considered too large. 5000 miles implies an average daily use of 33 miles.
2.	TDAYS	<151	Allows for 5 months of use.
3.	DAYSREC	<151	Allows for 5 months of use.
4.	DAYSWIMN	<151	Allows for 5 months of use.
5.	MILEWIMN	<251	Allows up to 250 miles traveled each day.
6.	DAYSOUMN	<151	Allows for 5 months of use.
7.	MILEOUMN	<251	Allows up to 250 miles traveled each day.
8.	MPG	<28,>2	Per manufacturer data.

TABLE 1: Total Miles Traveled in 1990-91

Miles	Frequency	Percent	Valid Percent	Cum Percent
not used (0)	128	13.6	13.8	13.8
1-50	141	15.0	15.2	29.1
51-250	227	24.1	24.5	53.6
251-450	127	13.5	13.7	67.4
451-650	88	9.4	9.5	76.9
651-850	49	5.2	5.3	82.2
851-1050	39	4.1	4.2	86.4
1051-1250	29	3.1	3.1	89.5
>1250	97	10.3	10.5	100.0
	15	1.6	Missing	
	940	100.0	100.0	

Mean	461.146	Sum	426560
Valid cases	925	Missing cases	15

TABLE 2: Total Days of Use in 1990-91

Days	Frequency	Percent	Valid Percent	Cum Percent
not used (0)	131	13.9	14.1	14.1
1-7 days	232	24.7	25.1	39.2
8-14 days	164	17.4	17.7	56.9
15-21 days	139	14.8	15.0	71.9
22-28 days	41	4.4	4.4	76.3
29-35 days	125	13.3	13.5	89.8
36-42 days	20	2.1	2.2	92.0
43-49 days	10	1.1	1.1	93.1
50-56 days	14	1.5	1.5	94.6
57-63 days	19	2.0	2.1	96.7
64-70 days	4	.4	.4	97.1
71-77 days	3	.3	.3	97.4
78-84 days	1	.1	.1	97.5
85-91 days	8	.9	.9	98.4
92-98 days	2	.2	.2	98.6
99-105 days	8	.9	.9	99.5
>112 days	5	.5	.5	100.0
	14	1.5	Missing	
	940	100.0	100.0	

Mean	17.376	Sum	16090.0
Valid cases	926	Missing cases	14

TABLE 3: Number of Days Use for Recreation in Minnesota in 1990-91

Days	Frequency	Percent	Valid Percent	Cum Percent
0 days	159	16.9	17.2	17.2
1-7 days	253	26.9	27.4	44.6
8-14 days	153	16.3	16.6	61.2
15-21 days	133	14.1	14.4	75.6
22-28 days	47	5.0	5.1	80.7
29-35 days	101	10.7	10.9	91.7
36-42 days	11	1.2	1.2	92.8
43-49 days	11	1.2	1.2	94.0
50-56 days	14	1.5	1.5	95.6
57-63 days	12	1.3	1.3	96.9
64-70 days	2	.2	.2	97.1
71-77 days	4	.4	.4	97.5
78-84 days	1	.1	.1	97.6
85-91 days	7	.7	.8	98.4
92-98 days	2	.2	.2	98.6
99-105 days	8	.9	.9	99.5
>112 days	5	.5	.5	100.0
	17	1.8	Missing	
	940	100.0	100.0	

Mean	15.646	Sum	14441
Valid cases	923	Missing cases	17

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TABLE 4: Number of Days Use for Ag/Farming Purposes in 1990-91

Days	Frequency	Percent	Valid Percent	Cum Percent
0 days	828	88.1	89.5	89.5
1-7 days	64	6.8	6.9	96.4
8-14 days	18	1.9	1.9	98.4
15-21 days	8	.9	.9	99.2
29-35 days	4	.4	.4	99.7
50-56 days	2	.2	.2	99.9
57-63 days	1	.1	.1	100.0
	15	1.6	Missing	
	940	100.0	100.0	

Mean	.866	Sum	801.0
Valid cases	925	Missing cases	15

TABLE 5: Number of Days Use on Developed (maintained) Trails in Minnesota in 1990-91

Days	Frequency	Percent	Valid Percent	Cum Percent
0 days	377	40.1	40.6	40.6
1-7 days	247	26.3	26.6	67.2
8-14 days	113	12.0	12.2	79.3
15-21 days	88	9.4	9.5	88.8
22-28 days	30	3.2	3.2	92.0
29-35 days	44	4.7	4.7	96.8
36-42 days	6	.6	.6	97.4
43-49 days	4	.4	.4	97.8
50-56 days	3	.3	.3	98.2
57-63 days	6	.6	.6	98.8
71-77 days	1	.1	.1	98.9
78-84 days	4	.4	.4	99.4
85-91 days	1	.1	.1	99.5
92-98 days	1	.1	.1	99.6
99-105 days	2	.2	.2	99.8
>112 days	2	.2	.2	100.0
	11	1.2	Missing	
	940	100.0	100.0	

Mean 8.288 Sum 7700.0
Valid cases 929 Missing cases 11

- -

TABLE 6: Number of Miles per Day on Developed (maintained) Trails in Minnesota in 1990-91

Miles	Frequency	Percent	Valid Percent	Cum Percent
0	364	38.7	40.6	40.6
1-10	72	7.7	8.0	48.6
11-20	84	8.9	9.4	58.0
21-30	87	9.3	9.7	67.7
31-40	59	6.3	6.6	74.2
41-50	69	7.3	7.7	81.9
51-60	27	2.9	3.0	84.9
61-70	16	1.7	1.8	86.7
71-80	40	4.3	4.5	91.2
81-90	8	.9	.9	92.1
91-100	39	4.1	4.3	96.4
>100	32	3.4	3.6	100.0
	43	4.6	Missing	
	940	100.0	100.0	

Mean 27.921 Sum 25045
Valid cases 897 Missing cases 43

TABLE 7: Number of Days Use on Developed (maintained) Trails Outside of Minnesota in 1990-91

Days	Frequency	Percent	Valid Percent	Cum Percent
0 days	783	83.3	84.1	84.1
1-7 days	98	10.4	10.5	94.6
8-14 days	30	3.2	3.2	97.9
15-21 days	11	1.2	1.2	99.0
22-28 days	6	.6	.6	99.7
29-35 days	2	.2	.2	99.9
36-42 days	1	.1	.1	100.0
	9	1.0	Missing	
	940	100.0	100.0	

Mean	1.209	Sum	1126
Valid cases	931	Missing cases	9

- -

TABLE 8: Number of Miles per Day Use on Developed (maintained) Trails Outside of Minnesota in 1990-91

Miles	Frequency	Percent	Valid Percent	Cum Percent
0	774	82.3	84.4	84.4
1-10	7	.7	.8	85.2
11-20	10	1.1	1.1	86.3
21-30	9	1.0	1.0	87.2
31-40	6	.6	.7	87.9
41-50	18	1.9	2.0	89.9
51-60	13	1.4	1.4	91.3
61-70	8	.9	.9	92.1
71-80	14	1.5	1.5	93.7
81-90	4	.4	.4	94.1
91-100	26	2.8	2.8	96.9
>100	28	3.0	3.1	100.0
	23	2.4	Missing	
	940	100.0	100.0	

Mean	12.316	Sum	11294
Valid cases	917	Missing cases	23

TABLE 9: Users Estimate of MPG for 1990-91

MPG	Frequency	Percent	Valid Percent	Cum Percent
4.0	1	.1	.2	.2
4.5	2	.2	.3	.5
5.0	5	.5	.9	1.4
6.0	10	1.1	1.7	3.1
7.0	6	.6	1.0	4.2
7.5	1	.1	.2	4.3
8.0	21	2.2	3.6	8.0
8.5	1	.1	.2	8.1
9.0	14	1.5	2.4	10.6
9.2	1	.1	.2	10.7
10.0	116	12.3	20.1	30.8
10.5	1	.1	.2	31.0
11.0	26	2.8	4.5	35.5
11.2	1	.1	.2	35.7
11.4	1	.1	.2	35.9
11.5	2	.2	.3	36.2
12.0	65	6.9	11.3	47.5
12.5	2	.2	.3	47.8
13.0	25	2.7	4.3	52.2
13.5	2	.2	.3	52.5
14.0	30	3.2	5.2	57.7
14.5	1	.1	.2	57.9
15.0	89	9.5	15.4	73.3
16.0	17	1.8	2.9	76.3
16.5	1	.1	.2	76.4
17.0	20	2.1	3.5	79.9
17.5	2	.2	.3	80.2
18.0	21	2.2	3.6	83.9
18.5	1	.1	.2	84.1
19.0	3	.3	.5	84.6
20.0	62	6.6	10.7	95.3
21.0	6	.6	1.0	96.4
22.0	4	.4	.7	97.1
22.5	1	.1	.2	97.2
24.0	2	.2	.3	97.6
25.0	14	1.5	2.4	100.0
	363	38.6	Missing	
	940	100.0	100.0	

Mean 13.656
Valid cases 577 Missing cases 363

TABLE 10: Respondents Wanting a Copy of the Report

Response	Frequency	Percent	Valid Percent	Cum Percent
No	824	87.7	87.7	87.7
Yes	116	12.3	12.3	100.0
	940	100.0	100.0	

Valid cases 940 Missing cases 0

APPENDIX B: Survey Forms

TEXT OF SURVEY QUESTIONNAIRE

Survey of Registered Snowmobile Use

These survey questions pertain only to the use of the snowmobile identified on the sticker on the front of this postcard. Please answer the following questions with regard to that snowmobile only. Do not give answers about snowmobiling you did on another machine.

1. During the winter of 1990-1991:
   - How many **total miles** did you put on the snowmobile identified on the sticker? _____total miles
   - How many **total days** was this snowmobile used? _____total days
   - On how many **days** was this snowmobile used for **recreation** in Minnesota? _____days
   - On how many **days** was this snowmobile used for **agricultural** or **farming purposes**? _____days

2. During the winter of 1990-1991, on how many **days** was the snowmobile used on developed (maintained), signed snowmobile trails **WITHIN MINNESOTA**? _____days What was the average number of **miles** snowmobiled per day on those trails? _____miles

3. During the winter of 1990-1991, on how many **days** was this snowmobile used on developed (maintained), signed snowmobile trails **OUTSIDE OF MINNESOTA**? _____days What was the average number of **miles** snowmobiled per day for those trips outside of Minnesota? _____miles

4. What was the average number of **miles-per-gallon (MPG)** for the snowmobile identified on the sticker during the 1990-1991 winter? _____MPG

Thank you! Please drop the completed survey in the mail.

TEXT OF LETTER ACCOMPANYING SURVEY QUESTIONNAIRE

UNIVERSITY OF MINNESOTA

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Fax: 612-625-5212

November 1st, 1991

Dear Registered Snowmobile Owner:

The University of Minnesota is conducting a study on the 1990-1991 winter snowmobile season for use by the Minnesota Department of Natural Resources (DNR). As you may know, the DNR spends over two million dollars per year to develop, maintain and administer snowmobile trails.

The snowmobile you own, which is identified on your survey, has been selected in a random sample of Minnesota's registered snowmobiles for this study. Enclosed you will find a survey. Please complete the survey and drop it in the mail within one week after receiving this letter. The survey is postage paid and return addressed. Total time commitment on your part should not exceed five minutes.

Because your response will represent the use patterns of 200 other snowmobiles, it is important that you complete the questions as accurately as possible. Remember, you are to answer the questions only for the use of the snowmobile identified on the sticker on the front of the enclosed survey. Do not give answers about snowmobiling you did on another machine. Your answers will remain confidential.

The results of this study will be made available to all interested parties. You may receive a summary of results by writing "Copy of Results Requested" on the front of the survey.

Thank you for your help!

Sincerely,

Dorothy H. Anderson, PhD
Study Coordinator
(612) 624-2721

TEXT OF FIRST FOLLOW-UP REMINDER

11/18/91

Dear Registered Snowmobile Owner:

The University of Minnesota would like to thank you for participating in our study of the 1990-1991 winter snowmobile use. We look forward to receiving your survey.

If you have already returned your survey, please disregard this notice. If not, please mail it at your earliest convenience.

Thank you!

Sincerely,

Dorothy Anderson
Study Coordinator
(612) 624-2721

TEXT OF SECOND FOLLOW-UP REMINDER

UNIVERSITY OF MINNESOTA

Twin Cities Campus

Department of Forest Resources
College of Natural Resources

115 Green Hall
1530 North Cleveland Avenue
St. Paul, MN 55108-1027
U.S.A.
Fax: 612-625-5212

December 2, 1991

Dear Registered Snowmobile Owner:

Approximately 4 weeks ago you received a survey asking about your snowmobile use during the 1990-1991 winter. If you have already returned the survey, please accept our thanks. If not, we have enclosed another survey in case the original was not received or was misplaced.

We hope you will take 5 minutes to complete the survey and return it to us. The post card on which the survey is printed is already postage paid and return addressed. If you have any questions about the survey please call collect at the number below.

The results of this study will be made available to all interested parties. You may receive a summary of results by writing "Copy of Results Requested" on the front of the survey.

Thank you for your help!

Best regards,

Dorothy Anderson
Study Coordinator
(612) 624-2721

APPENDIX C:
Spreadsheet Regression Formula & Example

Regression Spreadsheet/ Formula

	A	B	C
1	Case = Year	(Y) = Dep Var.	(X) = IND Var
2		gasc per person	1/25 snow depth-G. Marais
3	1985	20.5	4
4	1986	31.9	18
5	1987	18.6	15
6	1989	51	43
7	1990	36.4	18
8	1991	39.8	26
9	SUM	=SUM(B3+B4+B5+B6+B7+B8)	=SUM(C3+C4+C5+C6+C7+C8)
10	MEAN	=(B9/B12)	=(C9/C12)
11	SUM Squared	=SUM((B3*B3)+(B4*B4)+(B5*B5)+(B6*B6)+(B7*B7)+(B8*B8)	=SUM((C3*C3)+(C4*C4)+(C5*C5)+(C6*C6)+(C7*C7)+(C8*C8))
12	N	6	6
13			
14	sum of Y sq =	=(B11-((B9*B9)/B12))	
15	sum of X sq =	=(C11-((C9*C9)/C12))	
16	sum of XY =	=(D9-((B9*C9)/B12))	
17			
18	regression	=B16/B15	
19	coeffecient		
20	(b)		
21			
22	1991 X =	26	
23			
24	1991 Y' =	=E18+(B18*B22)	
25	total		
26	consumption		
27	n=191715	=B24*191715	

Regression Spreadsheet/ Formula

	D	E	F
1	X*Y	Prediction	Error
2		Y'=a+bX	d=Y-Y'
3	=B3*C3	=SUM(E18+(B18*C3))	=B3-E3
4	=B4*C4	=SUM(E18+(B18*C4))	=B4-E4
5	=B5*C5	=SUM(E18+(B18*C5))	=B5-E5
6	=B6*C6	=SUM(E18+(B18*C6))	=B6-E6
7	=B7*C7	=SUM(E18+(B18*C7))	=B7-E7
8	=B8*C8	=SUM(E19+(B18*C8))	=B8-E8
9	=SUM(D3+D4+D5+D6+D7+D8		=SUM(F3+F4+F5+F6+F7+F8)
10			
11			=SUM((F3*F3)+(F4*F4)+(F5*F5)+(F6*F6)+(F7*F7)+(F8*F8))
12			sum of the SQ. Errors
13			
14			
15			
16			
17			
18	Intercept Constant (a)	=B10-(B18*C10)	
19			
20			
21			
22			
23			
24			
25			
26			
27			

G. Marals Snow Depth vs Gas pe

	A	B	C	D	E	F
1	Case = Year	(Y) = Dep Var.	(X) = IND Var	X*Y	Prediction	Error
2		gasc per vehicle	1/25 snow depth-G. Marais		Y'=a+bX	d=Y-Y'
3	1985	20.5	4	82	18.89734	1.60266249
4	1986	31.9	18	574.2	30.77157	1.128425998
5	1987	18.6	15	279	28.22709	-9.627094753
6	1989	51	43	2193	51.97557	-0.975567737
7	1990	36.4	18	655.2	30.77157	5.628425998
8	1991	39.8	26	1034.8	22.05215	17.74784652
9	SUM	198.2	124	4818.2		15.50469851
10	MEAN	33.03333333	20.66666667			
11	SUM Squared	7293.82	3414			444.1397932
12	N	6	6			sum of the SQ. Errors
13						
14	sum of Y sq =	746.6133333				
15	sum of X sq =	851.3333333				
16	sum of XY =	722.0666667				
17						
18	regression	0.848159749		Intercept Constant (a)	15.5047	
19	coeffecient					
20	(b)					
21						
22	1991 X =	26				
23						
24	1991 Y' =	37.556852				
25	total					
26	consumption					
27	n=191715	7200211.881				