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Fuel Used for Off-Highway Recreation

Patricia S. Hu
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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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ABSTRACT

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) established a National Recreational Trails Funding Program and the National Recreational Trails Trust Fund. ISTEA requires that tax revenue generated from the sales of motor fuel used for off-highway recreation be transferred from the Highway Trust Fund to the Trails Trust Fund for recreational trail and facility improvements. In order to apportion the Trails Trust Fund to individual states equitably, the Federal Highway Administration (FHWA) asked the Oak Ridge National Laboratory (ORNL) to estimate the amount of motor fuel used for off-highway recreation at the state level by different vehicle types. This report documents this estimation procedure.

For this estimation procedure, off-highway recreational fuel use was defined as Federally taxed gasoline, gasohol, diesel fuel, or special fuel used in recreational motorized vehicles on recreational trails or back country terrain. Fuel used in outdoor non-engine recreational equipment, such as camp stoves, heaters, and lanterns, was excluded from our analysis. Vehicle types included in this study were: pickup truck, light utility vehicle, motorcycle, all terrain vehicle (ATV), and snowmobile.

Two factors governed the development of this estimation procedure. First, individual state shares of the total Trust Funds need to be developed using a uniform approach. Second, data needed for the estimation procedure should be publicly available and easily obtainable so that estimates for all subsequent years can be generated easily. Estimates were developed based on existing data sources. Adjustment factors were developed to take into account different vehicular off-highway recreational usage among states.

Data are particularly sparse for motorcycles, ATVs and snowmobiles. Sparse data sources led to a number of assumptions in this estimation procedure. These assumptions typically reflect small state variations in vehicular off-highway recreational usage. In order to improve the estimates of vehicular off-highway recreational usage by state, future efforts need to acquire state-specific data.

1. INTRODUCTION

1.1 Background

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) established a National Recreational Trails Funding Program and the National Recreational Trails Trust Fund. ISTEA requires that motor fuel tax revenues generated from the sales of motor fuel for off-highway recreational purposes be transferred from the Highway Trust Fund to the Trails Trust Fund for recreational trail and facility improvements. The motivation behind this Program was that while taxes were generated from sales of motor fuel used primarily for off-highway recreational purposes, no commensurate benefits were received by those who made those purchases. The amounts to be transferred to the Trails Trust Fund are determined by the U.S. Department of Treasury and are subject to the amounts authorized in ISTEA and annual appropriation by the U. S. Congress.

Under the ISTEA, the Federal Highway Administration (FHWA) is charged with the development of state by state estimates of the amount of fuel used for off-highway recreational purposes. These estimates will be used to apportion funds available in the National Recreational Trails Trust Fund to individual states. For generating these estimates, off-highway recreational fuel use has been defined as Federally taxed gasoline, gasohol, diesel fuel, or special fuel used in recreational motorized vehicles on recreational trails or back country terrain. Both registered and unregistered recreational motorized vehicles are included. Fuel used in outdoor non-engine recreational equipment, such as camp stoves, heaters, and lanterns has been excluded. The bulk of such equipment burns a nontaxable fuel known as white gasoline or by the trade name Coleman fuel or propane which is taxable only when used on highways.

Charged with this mission, FHWA asked the Oak Ridge National Laboratory (ORNL) to develop a method to estimate the amount of motor fuel used for off-highway recreational purposes at the state level.

1.2 Parameters of Interest

Before an estimation procedure can be developed, it is essential to define clearly the parameters of interest. If a vehicle is used 35% of the time (i.e., 35% of the total annual miles) for off-highway recreational purposes, only a 0.35 full-vehicle-equivalent (FVE) is counted, and only fuel used for that 35% of the time is included in the tabulation. Two parameters of interest at the state level are:

$N_{i,j}$ = the number of the ith type of motorized vehicles ("full vehicle equivalent") used for off-highway recreational purposes in state j, and

$Gal_{i,j}$ = the total amount of fuel consumed by the ith type of "full vehicle equivalent" motorized vehicles for off-highway recreational purposes in state j,

where

$$i = \begin{cases} 1, & \text{for pickup trucks and light utility vehicles;} \\ 2, & \text{for motorcycles and all terrain vehicles (ATVs); and} \\ 3, & \text{for snowmobiles.} \end{cases}$$

These parameters can be expressed in a tabular format, as in Table 1. For estimation purposes, the reference year t is set at 1992. Historical time series data on $N_{i,j}$ and $Gal_{i,j}$ are used to forecast statistics for years beyond 1992.

Table 1. Number of Off-Highway Motorized Recreational Vehicles[1] and Their Corresponding Fuel Consumption for Year *t*

State[2]	Pickup Trucks and Utility Vehicles		Motorcycles and ATVs		Snowmobiles	
	Number	Fuel Use	Number	Fuel Use	Number	Fuel Use
AL	$N_{1,1}$	$Gal_{1,1}$	$N_{2,1}$	$Gal_{2,1}$	$N_{3,1}$	$Gal_{3,1}$
AR	$N_{1,2}$	$Gal_{1,2}$	$N_{2,2}$	$Gal_{2,2}$	$N_{3,2}$	$Gal_{3,2}$
AZ	$N_{1,3}$	$Gal_{1,3}$	$N_{2,3}$	$Gal_{2,3}$	$N_{3,3}$	$Gal_{3,3}$
CA	$N_{1,4}$	$Gal_{1,4}$	$N_{2,4}$	$Gal_{2,4}$	$N_{3,4}$	$Gal_{3,4}$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
WY	$N_{1,50}$	$Gal_{1,50}$	$N_{2,50}$	$Gal_{2,50}$	$N_{3,50}$	$Gal_{3,50}$
DC	$N_{1,51}$	$Gal_{1,51}$	$N_{2,51}$	$Gal_{2,51}$	$N_{3,51}$	$Gal_{3,51}$

[1] Full-vehicle-equivalent.
[2] Includes the District of Columbia.

The rest of this technical memorandum is organized as follows. Section 2 documents the procedures developed to estimate the number of light trucks that are used for off-highway recreational purposes ($N_{1,j}$), and the corresponding fuel use ($Gal_{1,j}$) for year t and state j. Section 3 provides this information for motorcycles and ATVs; and Section 4 does the same for snowmobiles. Many states have submitted to FHWA their estimates of fuel used for off-highway recreational purposes (in responding to the National Recreational Trails Funding Program). This report compares the states' estimates and ORNL's estimates. Additionally, plausible explanations of the differences between these two sets of estimates are given for each vehicle category. A computer program is developed to generate vehicle stock estimates ($N_{i,j,t}$) and fuel use estimates ($Gal_{i,j,t}$). Appendix A includes the documentation for this program.

1.3 General Modeling Approach

Estimates of the number of vehicles used for off-highway recreational purposes are mostly based on registration data, with a number of adjustment factors. The general relationship may be expressed as:

$$\hat{N}_{i,j,t} = Reg_{i,j,t} \times c_1 \times c_2 \times c_3 \qquad (1)$$

where $\hat{N}_{i,j,t}$ = the estimated number of the ith type of motorized vehicles ("full vehicle equivalent") used for off-highway recreational purposes in state j year t,

$Reg_{i,j,t}$ = the number of type i vehicles registered in state j and year t;

c_1 = adjustment factor for unregistered vehicles;

c_2 = adjustment factor for vehicle being "used off-highway"; and

c_3 = adjustment factor for vehicle being "used for recreational purposes."

Fuel used for off-highway recreational purposes is calculated by multiplying the total number of vehicles $\hat{N}_{i,j,t}$ by the average annual fuel use for off-highway recreational purposes:

$$\hat{Gal}_{i,j,t} = \hat{N}_{i,j,t} \times Gal / Veh_{i,j,t} \quad (2)$$

where $\hat{Gal}_{i,j,t}$ = the estimated amount of fuel used by type i vehicles in state j during year t for off-highway recreational purposes; and

$Gal / Veh_{i,j,t}$ = the average annual amount of fuel used per type i vehicle in state j during year t for off-highway recreational purposes.

Several constraints played key roles in the development of this general modeling approach. First, the estimation procedures can only use data from existing sources, and preferably from sources with historical trends and with the likelihood of their continuing to be available. Second, the input data need to be publicly available and easily obtained. Therefore, this modeling approach does not make use of numerous locally available data.

2. PICKUP TRUCKS AND LIGHT UTILITY VEHICLES

2.1 Estimation Procedure

This section describes ORNL's computational procedures to estimate the total number of pickup trucks and light utility vehicles in each state which were used for off-highway recreational purposes and their corresponding fuel use. For the purpose of this study, "pickup trucks and light utility vehicles" (referred to as "light trucks" in the rest of this memorandum) include pickups, vans, minivans, and utility vehicles with a maximum gross vehicle weight less than or equal to

10,000 pounds. Specifically, straight trucks with the body type of a pickup, van, minivan, or utility vehicle with the maximum gross weight less than or equal to 10,000 pounds were included in the analysis. Where data were missing on the maximum gross weight, the average weight was used. As mentioned earlier, the total number of vehicles used for recreational purposes is defined as the total number of "full vehicle equivalents". In other words, if 30 percent of a vehicle's total annual driving is off-the-road for recreational purposes, then this vehicle is counted as 0.30 of a full vehicle equivalent.

In order to estimate the number of light-duty trucks used off-the-road for recreational purposes and their corresponding fuel use, the following data are needed for each state: (1) total number of light-duty trucks registered in each state ($Reg_{I,\ j,\ t}$), (2) the average vehicle miles traveled (VMT) for off-highway recreational purposes per truck, and (3) the average off-road fuel economy (miles per gallon (MPG)). Because no data source includes all the information needed for this calculation, several data sources have been used to estimate each variable.

The most comprehensive data source identified on the number of light-duty trucks used for off-highway recreational purposes in each state is the Truck Inventory and Use Survey (TIUS). As a national transportation survey, TIUS collects data on the physical and operational characteristics of the nation's truck population. The survey is required by law to be conducted every 5 years for years ending in 2 and 7. TIUS has been conducted by the U.S. Bureau of Census.

There are four major factors that make the TIUS the foundation for estimating the number of light-duty trucks that are operated off-highway for recreational purposes. **First**, TIUS respondents were asked to report the average percentage of the miles that the vehicle was operated off-the-road. The adjustment

factor c_2, as described in Equation 1, can be derived from these percentages. **Second**, these respondents were also asked to report the primary use (i.e., personal, business, or a combination of personal and business uses) for which their vehicles were typically operated during the TIUS years. Any vehicles primarily operated for business use are assumed to have no activities characterized as recreational. **Third**, information on truck weight, body type, and configuration was recorded so that light trucks which met the aforementioned criteria can be properly identified. **Fourth**, the TIUS excludes publicly-owned vehicles, ambulances, buses and motor homes from the survey. Consequently, no adjustment is necessary to eliminate activities of the publicly-owned vehicles from total aggregate estimates.

In the context of Equation (1), the adjustment factor c_1 for light truck estimates (adjusting for unregistered vehicles) is set at 1. This implies that all light trucks are assumed to be registered. Adjustment factor c_2, adjusting for off-the-road use, is simply the average percentage of the miles that a vehicle was used off-the-road as reported in TIUS. However, this input alone is not sufficient to estimate the percentage of the miles that a truck was operated off-highway for recreational purposes since it is possible that a truck was operated off-highway but not for recreational purposes. One example of this situation is vehicles used by the lumber industry, which are often operated off-the-road.

Since TIUS did not explicitly collect information on the percentage of the annual mileage that a vehicle was used off-the-road for recreational purposes, ORNL's estimation procedure assumed that the product of the percent miles used off-the-road and the percent miles used for personal use is a proxy of the probability that a truck will be used off-the-road for recreational purposes. This product provides the input for $c_2 \times c_3$ of Equation (1). However, $c_2 \times c_3$ was

derived differently depending on the type of operation classification (i.e., personal, business, or a combination of both) under which the truck was primarily operated.

If the vehicle was primarily used for personal purposes, c_3 (the adjustment factor for recreational use) is assumed to be one. The rationale is that if a truck is primarily operated for personal use, then it is highly likely that the vehicle is used off-the-road exclusively for recreational purposes. Therefore, the adjustment factor for "use for recreational purposes", c_3, is 1. On the other hand, if a truck is primarily operated for business, then the adjustment factor for "use for recreational purposes", c_3, is 0. If a truck is operated for a mixture of personal and business purposes, then the probability that this truck will be operated off-the-road for recreational purposes is approximated by the product of the percent miles used off-the-road and the percent miles used for personal purposes.

Base Year Calculation

Since the 1987 TIUS is the most recent one with publicly available data, the estimation procedure set 1987 as the base year and used the 1987 TIUS data to estimate $N_{1,j,87}$ and $Gal_{1,j,87}$.

Table 2 presents the estimation results for each state for 1987. The number of light trucks registered ($Reg_{1,j,87}$) was estimated by summing the expansion factors of individual sampled pickup trucks and light utility vehicles (EXPFAC, the mnemonic data name in the TIUS public use file for the expansion factor). The percentage of light trucks used off-the-road for recreational purposes was

Table 2. Estimate of 1987 Light Truck Population, Average VMT per Truck, Percent Miles and Percent Trucks Used for Off-the-road Recreational Purposes
Based on the 1987 Truck Inventory and Use Survey

	Number of Light Trucks Registered	Percent Trucks Off-the-road	Average VMT Per Truck	Percent Miles Off-the-road
Alabama	779,605	7.367	10,458	3.498
Alaska	147,252	3.892	8,650	3.193
Arizona	673,819	5.651	11,437	4.357
Arkansas	499,434	6.101	10,441	5.765
California	4,073,798	2.547	10,859	1.905
Colorado	830,825	5.077	9,801	4.228
Connecticut	368,130	4.008	10,796	3.220
Delaware	97,302	2.933	10,881	1.752
D.C.	16,932	3.787	9,558	2.289
Florida	1,686,602	3.069	11,719	3.090
Georgia	1,043,230	4.299	11,467	2.758
Hawaii	140,699	6.041	9,457	4.879
Idaho	271,568	6.474	9,481	5.252
Illinois	1,250,362	3.298	10,421	2.254
Indiana	905,827	3.807	10,370	2.403
Iowa	557,445	2.609	8,997	1.984
Kansas	583,485	4.644	9,392	3.040
Kentucky	690,473	4.699	10,215	3.233
Louisiana	812,373	4.728	11,438	3.240
Maine	215,457	5.246	10,760	3.912
Maryland	551,808	3.394	11,890	2.590
Massachusetts	549,355	2.447	12,026	1.636
Michigan	1,301,830	3.994	11,872	2.933
Minnesota	690,747	3.249	10,489	2.235
Mississippi	460,260	6.746	10,518	3.923
Missouri	868,234	3.653	11,569	3.180
Montana	258,134	6.404	8,249	5.797
Nebraska	347,118	4.468	10,054	2.575
Nevada	219,378	5.347	9,894	3.520
New Hampshire	194,097	4.426	12,023	3.151
New Jersey	631,449	4.810	11,575	3.729
New Mexico	407,234	7.615	11,189	7.331
New York	1,268,290	2.676	10,601	1.963
North Carolina	1,162,234	3.427	10,115	2.420
North Dakota	184,650	4.970	8,458	3.928
Ohio	1,458,828	2.326	10,850	1.751
Oklahoma	759,614	5.366	11,094	4.071
Oregon	722,388	3.849	8,990	2.583
Pennsylvania	1,389,534	3.826	10,191	2.885
Rhode Island	99,953	4.567	11,252	3.356
South Carolina	510,957	4.935	11,771	3.941
South Dakota	194,817	5.398	9,083	3.635
Tennessee	889,064	4.491	10,971	3.060
Texas	3,392,642	4.174	12,197	3.003
Utah	322,628	5.060	10,019	3.919
Vermont	109,826	4.952	11,319	3.108
Virginia	977,791	4.497	10,351	3.029
Washington	978,390	4.305	10,075	2.274
West Virginia	368,984	6.821	9,578	5.857
Wisconsin	655,074	3.734	10,349	2.643
Wyoming	187,252	8.142	8,780	5.575
U.S.A.	37,757,180		10,806	

Source: Generated from the 1987 Truck Inventory and Use Survey (TIUS) Public Use Tape.

estimated by the weighted average product of the percent miles that a truck was operated off-the-road (POFFRD) and the percent miles when it was used for personal purposes (PPTRAN). This percentage ranges from 2.3% for Ohio trucks to 8.1% for Wyoming trucks. The average annual miles traveled per truck was estimated by the weighted average of the miles driven in a year by individual trucks (ANNMIL). The percent of annual miles traveled off-the-road for recreational purposes was estimated by the weighted average product of the percentage of the miles that a truck was used off-the-road (POFFRD) and the percentage of the miles that it was used for personal purposes (PPTRAN), taking into account the annual miles driven by this truck (ANNMIL). All of the weighted averages are weighted by the sample expansion factors (EXPFAC).

Among 32,578 sampled trucks which qualified for this estimation procedure, ANNMIL data were missing for 3 trucks and POFFRD data were missing for 339 trucks. These missing values were imputed by specific body type and major operation classification (personal, business or mixed). The weighing procedure made sure that each truck carried its appropriate sampling weight, and all calculations were performed at the state level to maintain state specific estimates.

Projections Beyond Base Year

☞ Projections of the vehicle stock

Since the 1987 TIUS is the most recent survey for which data are available, a projection procedure was developed to estimate statistics for years beyond 1987. For years where auxiliary data are available, projections are accomplished by

applying various growth rates calculated by the auxiliary data. However, for years where no auxiliary data are available, projections are accomplished by an exponential smoothing technique. For example, the vehicle stock of vehicle type i in state j and year $t+1$ is projected as:

$$Reg_{i,\,j,\,t+1} = f\,[i,\,j,\,Reg_{i,\,j,\,t},\,\ldots,\,Reg_{i,\,j,\,t-l}] \qquad (3)$$

where $f[.]$ is a state-specific exponential smoothing model. This technique is recommended due to the relatively short time series available (usually ten years or less) and the ease of model maintenance.

To calculate the growth rates of the light truck vehicle stock, two data sources were evaluated: FHWA's *Highway Statistics* and the truck registration files compiled annually by R. L. Polk and Company. FHWA's data are based on registration data submitted by individual states. This data series reports privately-owned vehicles combined with commercial vehicles. To exclude commercial vehicles from the reported aggregate totals, the commercial vehicle share of the combined private and commercial vehicle total needs to be estimated. Furthermore, it is unclear whether FHWA's data series includes minivans. Due to these unresolved data issues, this data series was not used at this time in the estimation and the projection procedures.

R. L. Polk and Company also obtains its registration data from individual states. Although this data series is far from perfect in terms of meeting this project's goals in that its vehicle stock numbers include all trucks, Polk's data series has two desirable features. First, it has been used as TIUS's sampling frame -- the basis from which trucks were identified and selected to participate in the surveys. Since the 1987 TIUS is the foundation for estimating $N_{1,\,j,\,87}$ and $Gal_{1,\,j,\,87}$,

being TIUS' sampling frames provides a more compatible base for estimation purposes than other data sources. Second, it has been relatively consistent throughout the years in the types of vehicles included in its tabulations. Due to these two data features, the growth rates of light trucks were calculated based on Polk's data. These growth rates in conjunction with the 1987 base year estimates were used to estimate the total number of light trucks for years beyond 1987. The total number of light trucks for year $1987+l$ is estimated as:

$$Reg_{1,\,.\,(87+l)} = Reg_{1,\,.\,(87+l-1)} \times \frac{Reg_{1,\,.\,(87+l)}\ (Polk)}{Reg_{1,\,.\,(87+l-1)}\ (Polk)} \qquad (4)$$

where $l = 1, 2,\ldots,$ and $Reg_{1,\,.,\,87}$, the number of light trucks for the year 1987, was based on the 1987 TIUS. Table 3 presents the calculation results. The distribution of vehicle stock by state was assumed to remain constant. The total number of light trucks in 1992 was "shared" to individual states by using the state distribution estimated by the 1987 TIUS data. The number of light trucks (in terms of full-vehicle-equivalents) that were used off-the-road for recreational purposes in 1992 is estimated by multiplying the number of light trucks in individual states by the state-specific probability that a light truck is used off-the-road for recreational purposes. These state-specific probabilities were calculated using 1987 TIUS data and were assumed to be constant over time (Table 2). Table 4 reports the estimated numbers of light trucks used off-the-road for recreational purposes in 1992 and the distribution of these vehicles by state. Note that the estimates of the number of light trucks used off-highway for recreational purposes are in full-vehicle-equivalents.

Table 3. Estimated Growth Rates of Trucks and Total Number of Light Trucks From 1987 to 1992

Model Year	Total Trucks in Operation[1]	Growth rate	Estimated Total Number of *Light* Trucks
1987	47,344,000	-	37,757,180[2]
1988	50,222,000	1.061	40,052,406
1989	53,202,000	1.059	42,428,977
1990	56,023,000	1.053	44,678,745
1991	58,179,000	1.038	46,398,170
1992	61,172,000	1.051	48,785,109

[1] R. L. Polk data as reported in a table entitled "Motor Trucks in Operation by Model Year" in MVMA's "Motor Vehicle Facts & Figures '92".
[2] Generated from the 1987 TIUS Public Use Tape.

☞Projections of fuel use

A very similar approach was used to project the amount of fuel consumed for off-the-road recreational purposes. Since only the average number of miles traveled off-the-road for recreational purposes is known (Table 2), this mileage information needs to be converted to the amount of fuel consumed. First, growth rates of annual miles of travel (VMT) for light trucks were calculated using the average annual VMT for 2-axle 4-tire trucks as published in Table VM-1 of FHWA's *Highway Statistics*. VMT for 2-axle 4-tire trucks was used to calculate VMT growth rates because 2-axle 4-tire trucks better represent light trucks than other truck categories used in Table VM-1 of the *Highway Statistics*. VMT growth rates are, in turn, used to "expand" the 1987 VMT calculated by using the 1987 TIUS data. The reason for not directly using VMT statistics from the

Table 4. Estimated Number of Full Truck Equivalents Used Off-Road for Recreational Purposes, 1992

State	Projected Total Number of Light Trucks	Full Truck Equivalents Used Off-Road	
Alabama	1,007,308	74,208	(3.7%)
Alaska	190,261	7,405	(0.4%)
Arizona	870,625	49,199	(2.5%)
Arkansas	645,306	39,370	(2.0%)
California	5,263,653	134,065	(6.8%)
Colorado	1,073,488	54,501	(2.7%)
Connecticut	475,652	19,064	(1.0%)
Delaware	125,721	3,687	(0.2%)
D. C.	21,877	828	(0.0%)
Florida	2,179,216	66,880	(3.4%)
Georgia	1,347,931	57,948	(2.9%)
Hawaii	181,794	10,982	(0.6%)
Idaho	350,886	22,716	(1.1%)
Illinois	1,615,562	53,281	(2.7%)
Indiana	1,170,396	44,557	(2.2%)
Iowa	720,261	18,792	(0.9%)
Kansas	753,906	35,011	(1.8%)
Kentucky	892,143	41,922	(2.1%)
Louisiana	1,049,647	49,627	(2.5%)
Maine	278,387	14,604	(0.7%)
Maryland	712,977	24,198	(1.2%)
Massachusetts	709,808	17,369	(0.9%)
Michigan	1,682,062	67,182	(3.4%)
Minnesota	892,497	28,997	(1.5%)
Mississippi	594,690	40,118	(2.0%)
Missouri	1,121,823	40,980	(2.1%)
Montana	333,528	21,359	(1.1%)
Nebraska	448,502	20,039	(1.0%)

State	Projected Total Number of Light Trucks	Full Truck Equivalents Used Off-Road	
Nevada	283,453	15,156	(0.8%)
New Hampshire	250,788	11,100	(0.6%)
New Jersey	815,879	39,244	(2.0%)
New Mexico	526,177	40,068	(2.0%)
New York	1,638,726	43,852	(2.2%)
North Carolina	1,501,694	51,463	(2.6%)
North Dakota	238,582	11,858	(0.6%)
Ohio	1,884,915	43,843	(2.2%)
Oklahoma	981,478	52,666	(2.7%)
Oregon	933,379	35,926	(1.8%)
Pennsylvania	1,795,382	68,691	(3.5%)
Rhode Island	129,147	5,898	(0.3%)
South Carolina	660,195	32,581	(1.6%)
South Dakota	251,718	13,588	(0.7%)
Tennessee	1,148,737	51,590	(2.6%)
Texas	4,383,548	182,969	(9.2%)
Utah	416,860	21,093	(1.1%)
Vermont	141,903	7,027	(0.4%)
Virginia	1,263,379	56,814	(2.9%)
Washington	1,264,153	54,422	(2.7%)
West Virginia	476,755	32,519	(1.6%)
Wisconsin	846,405	31,605	(1.6%)
Wyoming	241,944	19,699	(1.0%)
TOTAL	48,785,109	1,982,564	(100.0%)

Highway Statistics for years beyond 1987 was that VMT statistics from the *Highway Statistics* include **all** 2-axle 4-tire trucks, while the base year 1987 VMT was calculated using a specific group of sample trucks that met the vehicle definition requirements of this study. Table 5 reports the average annual VMT per 2-axle 4-tire truck, VMT growth rates, and the estimated average annual VMT per light truck that met the vehicle definitions of this study for years beyond 1987.

Table 5. Estimated Growth Rates of Light Truck VMT and the Estimated Average VMT per Light Truck, 1987 - 1992

Year	Average VMT per Truck[1]	Growth Rate	Estimated Average VMT per Light Truck
1987	11,591	-	10,806[2]
1988	11,848	1.022	11,046
1989	11,982	1.011	11,171
1990	11,993	1.001	11,181
1991	12,103	1.009	11,283
1992	12,055	0.996	11,239

1 From Table VM-1 of the "Highway Statistics" under "2-Axle and 4-Tire" category.
2 Based on the 1987 TIUS.

To maintain the different levels of vehicle usage by each state, the 1992 average annual VMT per light truck in state *j* was calculated as:

$$\hat{VMT}_{1,\,j,\,92} = \frac{VMT_{1,\,j,\,87}}{VMT_{1,.,\,87}} \; x \; \hat{VMT}_{1,.,\,92} \qquad (5)$$

where $\hat{VMT}_{1,.,\,92}$ = the 1992 national average miles traveled per light truck projected by using the 1987 TIUS data and VMT growth rates calculated from the FHWA's data (Table 5), $\hat{VMT}_{1,.,\,92}$ = 11,239.

$VMT_{1,\,j,\,87}$ = the 1987 average miles traveled per light truck in state *j* (Table 2), and

$VMT_{1,.,\,87}$ = the national average miles traveled per light truck in 1987 (Table 2).

Using Equation (5), the 1992 average VMT per light truck for state *j* was estimated and presented in Table 6. The total number of miles traveled for off-the-road recreational purposes by trucks in state *j* was calculated by Equation (6).

$$_{off}\hat{VMT}_{1,\,j,\,92} = \hat{Reg}_{1,\,j,\,92} \times \hat{VMT}_{1,\,j,\,92} \times (c_2 \times c_3)_j \qquad (6)$$

where $\hat{Reg}_{1,\,j,\,92}$ is the number of light trucks registered in state *j* in 1992 (Table 4), and $(c_2 \times c_3)_j$ is the state-specific probability that a truck in state *j* is used for off-the-road recreational purposes (Table 2).

The amount of fuel used off-the-road for recreational purposes is derived as:

$$ {}_{off}\hat{Gal}_{1,\,j,\,92} = \frac{{}_{off}\hat{VMT}_{1,\,j,\,92}}{{}_{off}MPG_{1,.,\,92}} \qquad (7) $$

where ${}_{off}MPG_{1,.,\,92}$ is the estimated average 1992 off-the-road fuel economy of 2-axle 4-tire trucks and is estimated as:

$$ {}_{off}MPG_{1,.,\,92} = {}_{on}MPG_{1,.,\,92} \times 0.9 \qquad (8) $$

where ${}_{on}MPG_{1,.,\,92}$ is the average 1992 on-road fuel economy of 2-axle 4-tire trucks as reported in Table VM-1 of the *Highway Statistics* and 0.9 is the adjustment factor to take into account the difference between the on-road and the off-road fuel economies. This adjustment factor is based on data collected in the 1987 TIUS. Off-the-road fuel economy is assumed to be uniform among all states. The results are presented in Table 6. Also included in Table 6 is the average annual fuel used for off-the-road recreation per vehicle. Since the estimated number of vehicles used for off-the-road recreational purposes is expressed in full-vehicle-equivalents, one should **not** divide the amount of fuel used by the number of full-vehicle-equivalents used for off-the-road recreational purposes to derive the average amount of fuel use per truck for off-the-road recreation. Instead, this parameter should be calculated by dividing the amount of fuel used for off-the-road recreational purposes by the total number of light trucks.

Table 6. Projected Average Annual VMT per Light Truck and Estimated Fuel Use Off-Road for Recreational Purposes by State, 1992

State	Projected Average VMT per Light Truck	Total Fuel Used Off-Road (gal.)		Average Fuel Use Off-Road per Light Truck(gal.)
Alabama	10,877	29,612,540	(2.4%)	29
Alaska	8,997	4,222,881	(0.3%)	22
Arizona	11,895	34,863,870	(2.8%)	40
Arkansas	10,859	31,214,200	(2.5%)	48
California	11,294	87,501,790	(7.0%)	17
Colorado	10,194	35,747,660	(2.9%)	33
Connecticut	11,228	13,287,790	(1.1%)	28
Delaware	11,317	1,926,005	(0.2%)	15
D. C.	9,941	384,639	(0.0%)	18
Florida	12,188	63,415,330	(5.1%)	29
Georgia	11,926	34,257,590	(2.7%)	25
Hawaii	9,836	6,740,744	(0.5%)	37
Idaho	9,861	14,040,740	(1.1%)	40
Illinois	10,838	30,495,210	(2.4%)	19
Indiana	10,785	23,437,450	(1.9%)	20
Iowa	9,357	10,331,750	(0.8%)	14
Kansas	9,768	17,297,930	(1.4%)	23
Kentucky	10,624	23,676,820	(1.9%)	27
Louisiana	11,896	31,259,590	(2.5%)	30
Maine	11,191	9,416,821	(0.8%)	34
Maryland	12,366	17,644,210	(1.4%)	25
Massachusetts	12,508	11,222,520	(0.9%)	16
Michigan	12,348	47,067,690	(3.8%)	28
Minnesota	10,909	16,813,700	(1.3%)	19
Mississippi	10,939	19,719,110	(1.6%)	33
Missouri	12,032	33,165,950	(2.6%)	30
Montana	10,457	12,816,880	(1.0%)	38
Nebraska	8,579	9,330,951	(0.7%)	21
Nevada	10,290	7,933,052	(0.6%)	28
New Hampshire	12,505	7,635,064	(0.6%)	30
New Jersey	12,039	28,299,860	(2.3%)	35

State	Projected Average VMT per Light Truck	Total Fuel Used Off-Road (gal.)		Average Fuel Use Off-Road per Light Truck(gal.)
New Mexico	11,637	34,684,160	(2.8%)	66
New York	11,026	27,404,280	(2.2%)	17
North Carolina	10,520	29,539,800	(2.4%)	20
North Dakota	8,797	6,369,731	(0.5%)	27
Ohio	11,285	28,777,470	(2.3%)	15
Oklahoma	11,538	35,621,720	(2.8%)	36
Oregon	9,350	17,417,560	(1.4%)	19
Pennsylvania	10,599	42,419,390	(3.4%)	24
Rhode Island	11,703	3,919,044	(0.3%)	30
South Carolina	12,243	24,611,430	(2.0%)	37
South Dakota	9,447	6,678,720	(0.5%)	27
Tennessee	11,410	30,990,840	(2.5%)	27
Texas	12,686	129,026,500	(10.3%)	29
Utah	10,420	13,153,290	(1.0%)	32
Vermont	11,772	4,011,685	(0.3%)	28
Virginia	10,766	31,831,730	(2.5%)	25
Washington	10,479	23,274,490	(1.9%)	18
West Virginia	9,962	21,492,660	(1.7%)	45
Wisconsin	10,764	18,604,520	(1.5%)	22
Wyoming	9,132	9,516,966	(0.8%)	39
TOTAL		1,254,126,323	(100.0%)	

2.2 Comparison Between States' Estimates and ORNL's Estimates

Twenty-one of the 51 states (including the District of Columbia) reported their estimates of light trucks used for off-the-road recreational purposes to FHWA in January 1992. Several states conducted off-highway vehicle surveys to estimate the numbers of off-highway light trucks used for recreational purposes and the corresponding fuel use. These surveys are discussed in detail later in this section. Since most of the estimates were based on 1991 data, the comparison between states' estimates and ORNL estimates was for the year 1991 (Table 7). In general, ORNL's statewide estimates of the number of light trucks are relatively close to the states' estimates. As mentioned earlier, light trucks in this study are defined by ORNL as straight trucks with body types of a pickup, van, minivan, or utility vehicle and maximum gross weight less than or equal to 10,000 lbs.

Differences in vehicle classification by ORNL and by the states contribute to the discrepancy, if any, between the two sets of vehicle stock estimates. While ORNL's estimation procedure includes minivans and vans, most of the states did not include vans and minivans, and some did not include utility vehicles. The reason that Georgia, Louisiana, and Wyoming reported a greater number of light trucks than ORNL did was probably because they included all of the registered light trucks in their calculations.

The majority of ORNL's state estimates of fuel used for off-the-road recreational purposes are higher than individual states' estimates, except for the

Table 7. Comparison of ORNL's and State Estimates of Number of Light Trucks and Fuel Used for Off-Road Recreational Purposes, 1990-1991

	Total Number of Light Trucks (1000)		Total Fuel Used Off-Road (1000 Gal.)		Average Fuel Use Off-Road per Vehicle (Gal.)	
	ORNL Estimate	State Estimate	ORNL Estimate	State Estimate	ORNL Estimate	State Estimate
Alabama[1]	779.6	820.6	24,603	65,299	32	80
Alaska	181.0	135.5	3,988	356	22	3
Arizona[2]	797.3	759.0	32,281	N/A[3]	40	N/A
Arkansas[1]	499.4	512.1	25,933	52,862	52	103
California[4]	4,577.9	4,528.1	78,997	31,064	17	7
Colorado	1,021.0	362.7[5]	33,758	1,451	33	N/A
Delaware	119.6	5.7[6]	1,819	1,024	15	N/A
Georgia	1,282.0	1,399.1	32,351	6,296	25	5
Idaho[2]	321.4	306.7	13,001	10,126	40	48
Louisiana	998.3	1,245.1	29,520	10,954	30	9
Minnesota[2]	817.4	528.3	15,569	4,552	19	9
Mississippi	565.6	466.7	18,622	4,725	33	10
Nebraska	426.6	171.6[7]	8,812	4,719	21	N/A
New Mexico	500.4	456.8	32,754	1,978	65	4
New York	1,558.5	39.6[7]	25,879	3,477	17	N/A
North Dakota	226.9	212.1	6,015	937	27	4
Oklahoma	933.5	184.3[7]	33,639	9,217	36	N/A
Oregon	887.7	3.8[8]	16,448	8,476	19	223
Pennsylvania	1,707.5	1,277.5	40,059	192	23	0.2
Rhode Island	122.8	99.5[9]	3,701	362	30	4
South Dakota[2]	230.5	193.7	6,184	2,124	27	11
Washington	1,202.3	270.9[10]	21,979	29,947	18	N/A
Wyoming	230.1	215.2	8,987	3,076	39	14
Total			482,618	253,214		

[1] 1987 data.

[2] 1990 data.

[3] Data are not available.

[4] 1989 data as reported in Tyler and Associates, A Study to Determine Fuel Tax Attributable to Off-Highway and Street Licensed Vehicles Used for Recreation Off-Highway.

[5] Registered 4-wheel drive pickups only.

[6] Registered surf fishing vehicles only.

[7] Off-road recreational vehicle only.

[8] Vehicles registered as of June 30, 1991 include dune buggies, jeeps, and other 4x4's, motor vehicles that weigh more than 600 but less than 8,000 pounds.

[9] Light trucks from 4,000 - 10,000 pounds only.

[10] Off-road pickups only.

states of Alabama, Arkansas, and Washington. Two plausible explanations for Alabama's estimate of fuel used for off-the-road recreational purposes being almost two and half times higher than ORNL's estimate are: (1) the Alabama Highway Department assumed that 6.6% of the annual driving was for off-the-road recreational purposes while ORNL's estimate was 3.5% (Table 2) which was derived using the 1987 TIUS data; and (2) Alabama's mileage estimates are converted to fuel consumption by setting the average fuel economy at 10, while ORNL used adjusted FHWA's national estimate of 14.3 miles per gallon for 2-axle 4-tire trucks. The difference in the fuel economy estimate itself introduces a 30% difference in the fuel consumption estimate.

In the case of Arkansas, all recreational travel was assumed to be off-the-road recreational travel. It amounted to 13.3% of total travel. Based on the 1987 TIUS data, the percent miles traveled by light trucks for off-the-road recreational purposes in Arkansas was 5.8% (Table 2). This difference alone contributes to Arkansas' estimate being double that of ORNL's.

In its effort to determine the proportion of motor vehicle fuel sold to snowmobiles and other off-road vehicles, the state of Washington conducted two studies: the *1986 Washington State Off-Road Vehicle Study*, and the *1990-1991 Snowmobile Fuel Use Study*. Given Washington's estimate of 270,900 off-road pickups and TIUS' estimate of 1,202,300 light trucks in Washington, 22.5% of all light trucks in Washington were assumed to be off-the-road pickups (270,900 ÷ 1,202,300 = 22.5%). Applying Washington's estimate that 44% of its off-road pickup trucks (4x4s) were used for recreational purposes, the percentage of the total light trucks used off-highway for recreational purposes in Washington is estimated to be 9.9% (22.5% x 44.0%). This percentage is conservative since it assumes that only off-road vehicles are operated off-the-road. Nonetheless, this

percentage estimate is more than double the ORNL estimate of 4.3% (Table 2). This difference probably contributes significantly to the difference in estimated fuel use for off-the-road recreational purposes.

The following discussion focuses on off-road vehicle surveys conducted by individual states.

Arizona

Two different surveys were conducted during 1989-1990 -- one for the winter and one for the summer season. Each survey covered a six month period and contacted 1,000 households using a random dialing procedure that selected a number of telephone numbers in proportion to each county's population size. These initial contacts estimated that 17.5 percent of the households in the winter sample and 19.3 percent of the households in the summer sample drove their off-road vehicles off-highway at least once during the six months prior to the survey. A low response rate in the initial contacts led to additional phone calls. Overall, 331 households indicated that they had driven their off-road vehicles off-highway during the six-month sample period in the Winter of 1989, and 353 households indicated that they had driven their off-road vehicles off-highway during the six-month sample period in the Summer of 1990. Unfortunately, the reported survey results do not include any usage information by vehicle class. Table 8 summarizes the population estimates.

Table 8. Results from the 1990 Arizona Off-Highway Vehicle Survey
4x4 Pickups & Vans/Trucks

	Estimated Total Truck Population	Estimated Off-road Truck Population
Based on the Winter Survey	798,906	103,579
Based on the Summer Survey	719,015	219,642
Survey Average	758,961	161,611
ORNL Estimates	797,348	215,503[1]
% Difference between ORNL's and Arizona's Estimates	5%	33%

[1] Used off-the-road for recreation purposes at some time.

Source: Virden, R. J., et. al., " The 1990 Arizona Off-Highway Vehicle Survey," Prepared for the Arizona Departments of Transportation and Game and Fish, and Arizona State Parks Board. Arizona State University, Tempe, Arizona, January 1991.

California

A randomly selected sample of 20,394 households were contacted. Of those, 12,156 surveys were completed, yielding a response rate of almost 60%. The sample covered 53 of California's 58 counties. The sample was selected in proportion to each county's population size. The 5 counties which were not covered in the survey each represents no more than one-tenth of one percent of the state's total population. All panelists were interviewed four times, once every three months. Each respondent was sent a reminder postcard that notified him/her when he/she would be contacted (or re-contacted). Each respondent was also provided a diary to keep track of his/her off-road fuel use. Whether the sampled off-highway vehicles were registered was determined by matching the sampled vehicles with California's Department of Motor Vehicles' registration file of off-highway vehicles. Based on the matching results, a correction factor was

computed to estimate the total number of off-road vehicles of a particular class. This factor was the ratio of unregistered vehicles to registered vehicles.

Light trucks were categorized in two groups: 4-wheel drive and 2-wheel drive. These vehicles include pickups, vans, and utility vehicles (including dune buggies). Survey results indicate that 36.1% of all street licensed 4-wheel drive trucks were used off-the-road at some time during the 12-month period prior to the survey, and 13.9% of the street licensed 2-wheel drives were similarly used. Survey results also suggested that out of 95 sampled non-street vehicles, only 11 could be matched with California DMV's registration files, indicating that 88% of non-street vehicles were unregistered. This implies an adjustment factor of 7.6 for unregistered light trucks. Any problem with the matching procedure could easily result in an over- or (under) estimate of the ratio of unregistered vehicles to registered vehicles. Table 9 presents the resulting population estimate of off-road light trucks.

A direct comparison between ORNL's and California's estimates is not straightforward. The types of vehicles included in the estimation procedure are different. ORNL's estimation procedure includes all registered pickups, vans, utility vehicles and minivans while California includes all pickups, vans and utility vehicles, but not minivans, regardless of whether the vehicles are registered or not. On average, ORNL estimated that each light truck used 17 gallons a year for off-road recreational purposes while California derived separate fuel use estimates for different vehicle classes (Table 9). Table 7 presents a comparison between these two sets of light truck estimates.

Table 9. 1989 Off-Road Recreational Fuel Use of California Light Trucks

	Street Light Trucks		Non-Street Light Trucks
	4-Wheel Drive	2-Wheel Drive	4-Wheel Drive
Annual Fuel Use/Veh.	23.7	5.39	56.2
Number of Vehicles Registered	194,437	4,279,808	6,974
Correction Factor for Unregistered Vehicles	1.0	1.0	6.7
Total Population Estimate	194,437	4,279,808	53,700
Total Annual Fuel Use Estimate	4,607,885	23,076,502	3,019,452

Colorado

A mail survey was done of randomly-selected registered off-road vehicles. Unfortunately, there is little documentation of the survey results. Since no information is available regarding the important factors, such as the number of households surveyed or the response rate, etc., no assessment is made of the survey results. The State of Colorado estimated that eight percent of its total 362,700 4-wheel drive vehicles traveled off-the-road, resulting in an estimate of 29,016 off-highway 4-wheel drive vehicles. Each of these off-highway vehicles was assumed to use 50 gallons of fuel per year, yielding a total fuel use estimate of 1,450,800 gallons. The lack of documentation makes it impossible to evaluate the differences between ORNL's estimates and the State of Colorado's estimates.

Oregon

An off-road vehicle use survey was conducted on randomly-selected registered off-road vehicles. This survey was updated every four years as required by law. No effort was made to survey non-registered vehicles. A summary of the survey results is presented in Table 10. The survey response rate was about 70% which is reasonably good for a voluntary survey. These annual fuel consumption estimates illustrate the difference between consumption estimates reported directly by survey respondents and estimates computed by the average number of days operated off-road for recreational purposes (*Days*) and the average fuel use per day for off-the-road recreation purposes (*Gallons*). The fact that the average of the product of *Days* and *Gallons* [*Mean(Days*$\times$*Gallons)*] is greater than the product of the averages [*Mean(Days) x Mean(Gallons)*] indicates that *Days* and *Gallons* are positively correlated. Furthermore, there is no supporting evidence to believe that *Mean(Days* $\times$ *Gallons)* is a better estimate than the annual fuel use reported

Table 10. Estimated Number of Off-Highway Vehicles and Fuel Use in Oregon
(Based on Results from the 1989 Oregon Off-Road Vehicles Survey)

	Off-Highway Motorcycles	ATV's	Jeeps & 4x4s
Licensed vehicles	1,489	41,211	3,016
No. of vehicles surveyed	494	711	592
Competed surveys	374	513	402
No. of surveys without missing data	346	488	371
No. of vehicles used for recreation only	331	390	307
% of Working Sample, Recreation Only			
Not used for recreational purposes	0.05	0.25	0.21
Owning the vehicle less than a year	0.50	0.17	0.18
Number of days used for recreational purposes			
Average	33.0	34.9	30.6
Fuel Consumption on a Typical Day of Usage			
Average	2.4	2.9	6.4
Median	2.0	2.0	5.0
Estimated Fuel Consumption Annually per Vehicle			
Avg (Days x Gallons)	89.3	125.6	223.2
Avg (Days) x Avg (Gallons)	79.2	101.2	195.8
Reported in the survey	59.3	81.6	166.2
Estimated Total Annual Fuel Consumption			
Reported in the survey	132,968	5,176,102	673,171
Corrected for recreational use	126,942	3,875,440	532,836

directly by the survey respondents. Based on the survey results, an adjustment factor of 79% was derived to account for the fuel used off-road for recreational purposes.

A significant definitional difference between ORNL's procedure and the State of Oregon's procedure is that Oregon's 1989-1990 ATV Survey focused on ATV Class II vehicles which included only three classes of all terrain vehicles: dune buddies, jeeps, and other 4x4's motor vehicles that weigh more than 600 but less than 8,000 pounds. In March 1990, there were 3,016 Class II ATV licenses maintained by the Motor Vehicle Division of the Oregon Department of Transportation. This number of Class II ATV licenses indicates that Oregon's estimates are based on information collected from a sample of light trucks which are classified as ATVs, rather than a sample of light trucks that were used off-the-road for recreational purposes. Consequently, Oregon's estimates are significantly lower than ORNL's estimates (Table 7).

Washington

A telephone survey of 3,460 households was conducted in 1986 regarding off-road recreational vehicle usage in 1985. The method that was used to select telephone numbers is not documented. The sample size within each district in the State was proportional to the population of the counties making up the district. The survey identified 763 households owning one or more off-road vehicles (ORV). The parameters at the state level were then estimated by proportionally weighing the survey results by the sampling expansion factors. These estimates together with other relevant statistics are reported in Table 11. Also reported in Table 11 is a confidence range with an unspecified level of significance. A comparison with ORNL's estimates of the number of off-road light trucks in 1987

yields a difference of 43,919 (= 262,341-218,422) which is almost twice the reported confidence range (23,522).

A follow up mail survey was also conducted with the owners identified in the telephone survey. About 41% of these households returned a completed survey. The limited response rate decreases the reliability of the survey's results. Also, the survey did not include any questions regarding fuel consumption, information needed for our study.

Table 11. Results from 1986 Washington Off-Road Vehicle (ORV) Study
Sample size=3,460 Households

	No. Households in Survey Owning ORVs	% Households in Survey Owning ORVs	1985 Projected State-Wide Totals	Confidence Range
4 x 4s	450	13%	218,422	23,522
Dune buggies	35	1%	9,314	6,721
Dirt bikes	415	12%	195,740	23,522
ATVs	138	4%	73,927	15,122
ALL ORV	**763**	**20%**	**497,403**	**68,887**
ORNL's estimate of light trucks used off-road at some time for recreational purposes			262,341	

2.3 Concluding Notes

A direct comparison between state estimates and ORNL's estimates is still virtually impossible, despite the attempt to make these estimates as compatible as possible. As mentioned earlier, the total amount appropriated to the National Recreational Trails Trust Fund is authorized by the U.S. Department of Treasury on an annual basis. With a fixed amount of funding, FHWA faces the challenge of how to equitably apportion these funds to individual states based on the level of fuel used for off-road recreation. Two options are available to FHWA to address this challenge. The first one is to rely on the individual states to submit their annual estimates on off-highway recreational fuel use. The advantage of this option is that individual states could devote more resources to this activity, and can receive more cooperation in obtaining the data, than FHWA could. As a result, individual states might be able to produce more reliable estimates than FHWA could. However, more resources and more data do not guarantee more reliable estimates. The burden is then on the FHWA to verify the estimation methods employed by the individual states. This leads to two possible drawbacks if the first option is used. First, individual states have a great incentive to over-estimate their off-highway recreational fuel use. Second, the compatibility among states in estimating off-highway recreational fuel use becomes an enormous issue in trying to apportion the Trust Fund equitably. In addition, the third drawback of this option is that not every state submits the required estimate. In the 1992-1993 period, only twenty-three states did, and some of the estimates are for 1987 while others are for 1989 or 1990 (Table 7). Consequently, an estimation procedure would need to be developed for the remaining 22 states that failed to submit data, adding further complexity to the compatibility issue.

To overcome the disadvantages of the first option, a second option for FHWA to meet its challenge is to "standardize" the estimation procedure and develop a **common** tool which can objectively apportion the National Recreational Trails Trust Funds on an annual basis. Two factors characterize this option: (1) individual state shares of the total Trust Funds need to be developed using a uniform approach, and (2) data needed for the estimation purpose should be publicly available and easily obtainable so that the FHWA can generate these estimates for all subsequent years. It is these two factors that govern the development of ORNL's estimation procedure discussed in this report. It is also because of these two factors that ORNL's estimates are recommended over individual states' estimates. Of course, this option is not without its drawbacks. One major drawback is the failure to take advantage of more detailed state-specific information.

3. MOTORCYCLES AND ALL TERRAIN VEHICLES

3.1 Estimation Procedure

Data on motorcycles and all terrain vehicles (ATVs) are extremely sparse. Two basic sources of off-highway motorcycle and ATV fuel consumption estimates are the Motorcycle Industry Council (MIC) and individual states. Several western states have conducted surveys of off-highway motorcycle fuel consumption. These state level studies were each performed with different survey practices and they reported a wide range of estimates. Studies from Arizona, California, Colorado, Oregon, Utah and Washington will be discussed later in Section 3.2.

The MIC has reported state vehicle population estimates annually since 1985. These estimates are divided into three vehicle model categories: highway,

off-highway, and dual purpose. Since 1991, separate data were reported for ATVs. These state population estimates are computed by MIC from the annual retail sales of these vehicles in conjunction with the vehicle scrappage rates. Scrappage rates are based on user survey data. The accuracy of the resulting population estimate depends on the following factors: (1) the accuracy and coverage of state retail sales data, (2) the accuracy of the vehicle scrappage rates, and (3) the reasonableness of assuming zero net vehicle migration by vehicle vintage. Vehicle migration is the movement of vehicle registration from one state to the other. Even if the first two factors are correct, it might be reasonable to expect the migration issue to be problematic for southern and western states. From 1985 to 1990, more than 11% of the population in the South and West Regions had migrated there from other states[1] - the highest migration rate among all regions. Consequently, the MIC population estimates may have a downward bias for southern and western states.

The MIC also conducts periodic surveys of motorcycle and ATV usage. Unfortunately, this information is considered proprietary so that only limited access is permitted. The most recent 1990 survey covered 1,193 motorcycle and ATV owners in the United States. Further details regarding the survey method and the resulting response rate were not available. The distribution of annual miles driven is illustrated in Figure 1. This distribution is clearly skewed to the left with about 30% of the motorcycles and ATVs traveling 25 miles or less in the survey year. Using this survey information, the MIC estimated annual gasoline consumption to be 76 gallons per year. The method employed to obtain this estimate is summarized in Table 12. Since the MIC "believed the most accurate number for

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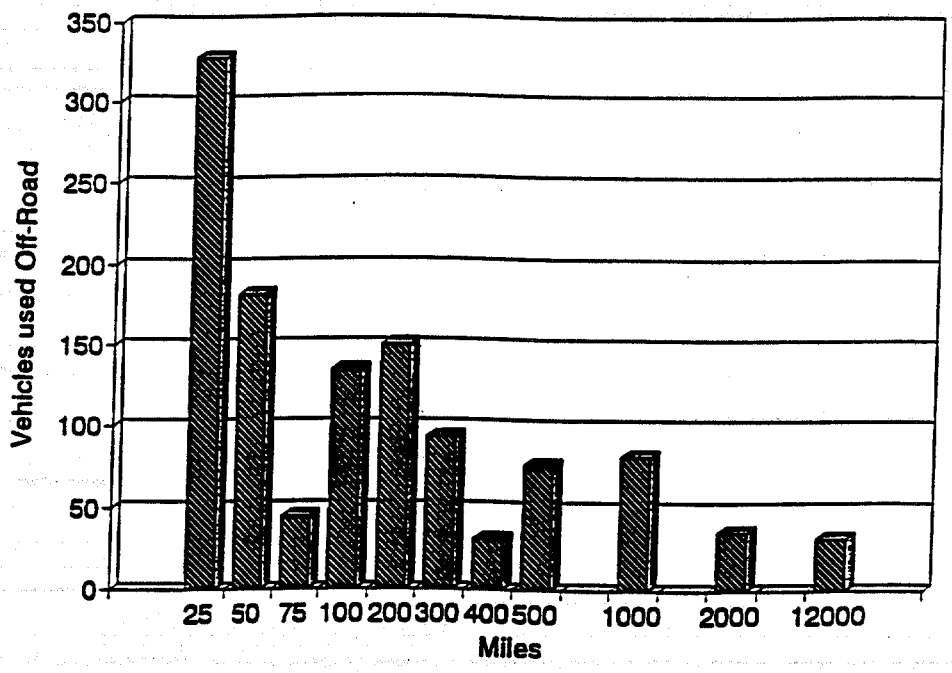
[1] Table No. 30. Statistical Abstract of the United States 1993. Bureau of the Census, U.S. Department of Commerce.

estimating days ridden per year and gasoline use per day is the average of the mean and median," the last column of Table 12 presents the averages of the mean (Column 1) and the median (Column 2).

Figure 1. Average Miles Ridden in the Past 12 Months Off-the-Road



Source: 1990 Survey of Motorcycle Ownership and Usage.

No reference is provided for this method of averaging the mean and median. Typically, the choice between the mean and median depends on prior information of the underlying distribution. If the distribution is thought to be normal or approximately normal, then the sample mean is the appropriate estimator. On the other hand, if the underlying distribution is Cauchy or nearly Cauchy, then the sample median is the appropriate estimator. When the underlying distribution is unknown, a "robust" estimator is preferable. This is an estimator which performs well for several different types of distributions, even though it may not be the best available for any particular distribution. Two such estimators proposed in the statistical literature are the "weighted mean" and the "trimmed mean", both of which yield the median estimate as a special case. Thus, when faced with evidence against a normal distribution, such as a large difference between mean and median, it may be advisable to use the median estimate over the mean estimate. This logic suggests that an estimate of 30 gallons per year for off-highway use may be more reasonable than either 76 or 143 gallons per year.

Table 12. MIC's Estimate of Annual Motorcycle Gasoline Consumption

	Mean (1)	Median (2)	MIC's Estimates (3)
Average number of days ridden per year off-highway	65	30	47.5
x			
Gallons of gasoline used per day	2.2	1.0	1.6
=			
Gallons used annually per vehicle off-highway	143	30	76

Source: 1990 Survey of Motorcycle Ownership and Usage.

Using Equ. (1) to estimate the number of motorcycles and ATVs used off-the-road for recreational purposes, c_1 (the adjustment factor for unregistered vehicles) is assumed to be 1. This is because the total number of motorcycles and ATVs estimated and reported by the MIC is a function of retail sales and has, supposedly, been adjusted for the number of unregistered vehicles. Since there is no state-specific information available on the percent time that a motorcycle or an ATV was used off-the-road, any vehicles that were used off-the-road at some time are enumerated. It was also assumed that whenever motorcycles were used off-the-road, they were for recreational purposes. Consequently, the adjustment factor for motorcycle's recreational use, c_3, is 1. Based on these assumptions, data series on the number of motorcycles and ATVs used off-highway some of the time is the basis to calculate the amount of fuel used off-the-road for recreational purposes. It is recognized that this data series does not accurately represent the number of motorcycles and ATVs used off-the-road for recreational purposes as expressed in full-vehicle-equivalence. Until the time that state-specific information becomes available on the percentage of the time that motorcycles and ATVs are used off-the-road for recreational purposes, this data series is considered sufficient to meet the project's goals. The number of motorcycles used off-highway at some time in 1992 is estimated by MIC and presented in Table 13.

As mentioned earlier, starting in 1991, motorcycles and ATVs data are reported separately. Some results from the MIC's survey on ATVs permit additional refinements to estimates of the number of ATVs used off-the-road for recreational purposes. Based on the survey responses on the percentages of off-road riding for utility purposes, Table 14 presents estimates of the average percent time for which an ATV was used for off-the-road recreational purposes. It is assumed that riding off-the-road, that is not for utility purposes, is for recreational

Table 13. Estimated Number of Motorcycles Used Off-Road for Recreational Purposes, 1992

State	Number of Motorcycles	State	Number of Motorcycles
Alabama	27,400	Montana	14,000
Alaska	6,000	Nebraska	8,300
Arizona	25,100	Nevada	13,396
Arkansas	17,600	New Hampshire	11,400
California	253,754	New Jersey	35,800
Colorado	31,900	New Mexico	14,300
Connecticut	18,100	New York	64,300
Delaware	3,308	North Carolina	42,800
D. C.	241	North Dakota	5,100
Florida	70,517	Ohio	52,200
Georgia	45,500	Oklahoma	26,100
Hawaii	--	Oregon	31,223
Idaho	24,100	Pennsylvania	62,200
Illinois	45,000	Rhode Island	5,000
Indiana	30,800	South Carolina	19,200
Iowa	16,200	South Dakota	5,500
Kansas	12,300	Tennessee	32,800
Kentucky	19,300	Texas	96,000
Louisiana	16,800	Utah	24,300
Maine	9,500	Vermont	4,100
Maryland	24,400	Virginia	36,200
Massachusetts	29,300	Washington	50,700
Michigan	52,500	West Virginia	16,700
Minnesota	25,800	Wisconsin	27,000
Mississippi	10,200	Wyoming	7,000
Missouri	22,300		

Source: 1992 Motorcycle Statistical Annual, Motorcycle Industry Council, Inc., Irvine, California.

purposes. After adjusting for non-recreational uses, the number of ATVs used off-the-road for recreational purposes is calculated and given in Table 15.

Table 14. Average Percent of ATVs Off-the-Road Riding for Recreational Purposes

Region	Percent of Off-the-road Riding for Recreational Purposes
East	*80.2*
Mid-West	*64.2*
South	*68.6*
West	*75.6*

Estimates from the MIC appear to reflect a high degree of uncertainty. Estimates of annual fuel consumption directly reported by the survey respondents were considered by the MIC to greatly underestimate actual fuel consumption. Nevertheless, these "underestimated" fuel uses and MIC's estimated annual miles driven imply an average fuel economy (MPG) of less than five -- significantly outside the range of the average motorcycle fuel economy of 35 to 75.

3.2 Synthesis of Average Motorcycle and ATV Fuel Use Estimates

Unlike light trucks, there is no survey of motorcycles and ATVs that allows consistent estimates of annual fuel use by state. Several options were considered to estimate annual fuel use. These include: applying MIC's estimate to all states; using state estimates for states where individual state surveys were conducted and applying MIC's estimate to states for which no surveys were conducted; and taking

Table 15. Estimated Number of ATVs Used Off-Road for Recreational Purposes, 1992

State	Number of ATVs	State	Number of ATVs
Alabama	44,764	Montana	12,026
Alaska	20,270	Nebraska	13,794
Arizona	26,624	Nevada	9,073
Arkansas	55,596	New Hampshire	11,394
California	137,720	New Jersey	22,869
Colorado	16,262	New Mexico	9,455
Connecticut	10,030	New York	63,953
Delaware	3,619	North Carolina	42,639
D. C.	0	North Dakota	5,774
Florida	45,311	Ohio	48,632
Georgia	50,934	Oklahoma	20,634
Hawaii		Oregon	29,671
Idaho	15,430	Pennsylvania	78,557
Illinois	29,513	Rhode Island	1,525
Indiana	30,026	South Carolina	16,041
Iowa	16,617	South Dakota	6,352
Kansas	11,548	Tennessee	50,249
Kentucky	29,477	Texas	77,601
Louisiana	44,764	Utah	24,128
Maine	15,005	Vermont	6,419
Maryland	15,968	Virginia	26,735
Massachusetts	15,727	Washington	26,094
Michigan	68,906	West Virginia	33,782
Minnesota	35,159	Wisconsin	31,245
Mississippi	34,002	Wyoming	7,337
Missouri	39,521		

advantage of all available estimates to derive a synthesized estimate. Since every survey has strengths and limitations, the last option of synthesizing all available estimates appears to be the most desirable.

In addition to the MIC's periodic surveys of motorcycle and ATV usage, six states have conducted surveys to estimate the number of off-road vehicles and fuel consumption. They are Arizona, California, Colorado, Oregon, Utah and Washington. These estimates are generated using very different approaches, with various limitations. To synthesize these estimates, a detailed evaluation of MIC survey and individual state surveys is imperative in order to obtain a set of subjective weights, one weight for each estimate. Estimates that are generated from more thorough surveys are given higher weights than those generated from less thorough approaches.

In general, all of the state studies estimated total gasoline consumption as the product of the estimated vehicle population and the annual gallons consumed per vehicle off-road for recreational purposes. However, a number of different approaches were used to estimate the annual fuel consumption per vehicle for off-road recreational purposes. The direct approach of simply using the survey respondents' estimates of total annual fuel used was typically not employed. Instead, the average annual fuel use for off-road recreational purposes was frequently estimated as:

$$Mean(Gallons) = Mean(Days) \times Mean(Dgallons) \quad (9)$$

where *Gallons* = fuel used annually per vehicle for off-highway recreational purposes,

Days = Number of days ridden per year off-highway for recreational purposes, and

Dgallons = Gallons used per day.

The stated reason for using this rather indirect approach is that the survey respondents were likely to underestimate the total annual fuel use. It was further suggested that a better estimate of total annual fuel use can be obtained from the survey respondents by asking for an estimate of the number of days ridden per year for off-highway recreational purposes and the average amount of fuel used per day, rather than by asking for the total annual fuel use directly. No related studies were cited to support this hypothesized survey response bias.

Consider the mathematical expression,

$$E\ (\ Gallons\ ) = E\ (\ Days\ ) \times E\ (\ Dgallons\ ) + Cov\ (\ Days,\ Dgallons\ ) \quad \textbf{(10)}$$

where E is the expectation operator. There is no reason to believe a priori that *Days* and *Dgallons* are uncorrelated (i.e., *Cov (Days, Dgallons)* = 0). Instead, one of two approaches is preferable to compute a representative summary measure such as the mean or the median. One approach is to compute the mean or the median of the direct survey responses on the total annual fuel use. The other approach is to compute the mean or the median of the product of *Days* and *Dgallons* [i.e., *Mean(Days* × *Dgallons)*].

In the following section, states' estimates of the number of off-highway motorcycles and their fuel use are examined in more detail. The diversity in

survey methods contributes to a large degree the wide variation in states' estimates of the average annual fuel use of off-highway motorcycles. Since comprehensive survey practices are very expensive, many of the state's survey efforts are limited. For example, only one state, California, attempted to estimate the use of unregistered vehicles. Most of the other states based their estimates on the number of registered vehicles, while some used an assumed correction factor to include unregistered vehicles. Although many of the state's off-highway vehicle surveys were discussed in Section 2.2, for completeness, these surveys are repeated here.

Arizona

Two different surveys were conducted -- one for the winter and one for the summer season. Each survey covered a six month period and contacted 1,000 households using a random dialing procedure that selected a number of telephone numbers in proportion to each county's population size. A low response rate in the initial contacts led to additional phone calls. Overall, 331 households indicated that they had driven their off-road vehicles off-highway during the six-month sample period in the Winter of 1989, and 353 households indicated that they had driven their off-road vehicles off-highway during the six-month sample period in the Summer of 1990. The reported survey results do not include any usage information by vehicle class. However, the results provide some useful information for the estimates of the number of motorcycles and ATVs used for off-the-road recreational purposes which are summarized in Table 16.

The large variation in total population estimates for motorcycles and ATVs between the two surveys indicates that a relatively large standard error is associated with these estimates. A comparison of the combined average of these two estimates, labeled "Motorcycles & ATVs (based on survey average)", with the

Table 16. Estimated Number of Arizona Motorcycles and ATVs Used Off-Highway
(Based on results from the 1990 Arizona Off-Highway Vehicle Survey)

	Estimated Total Vehicle Population	Estimated Off-road Vehicle Population
Motorcycles (Based on the Winter Survey)	154,455	36,287
Motorcycles (Based on the Summer Survey)	98,532	23,921
Motorcycles (Survey Average)	126,494	30,104
ATVs (Based on the Winter Survey)	83,885	27,748
ATVs (Based on the Summer Survey)	59,918	18,847
ATVs (Survey Average)	71,902	23,298
Motorcycles & ATVs (Survey Average)	198,395	53,402
Motorcycles & ATVs (Based on Arizona's DOT)	75,547	
Motorcycles & ATVs (Based on MIC)	104,400	

number of registered motorcycles and ATVs reported by the Arizona Department of Transportation yields an approximate estimate of the number of unregistered vehicles. The correction factor for unregistered vehicles, the ratio of unregistered to registered vehicles, is about 1.6 [(198,395 - 75,547)/75,547] -- an estimate several times smaller than that reported by California (to be discussed later). It is also interesting to note that 71% of the registered vehicles are used off-the-road (53,402/75,547=0.71). The corresponding MIC estimate of the total motorcycles and ATVs population for the State of Arizona is only 52% (104,400/198,395=0.52). This large discrepancy is hard to explain with just the vehicle migration issue, as discussed in Section 3.1, associated with the MIC vehicle population estimates.

California

A randomly selected sample of 20,394 households were contacted. Of those, 12,156 surveys were completed, yielding a response rate of almost 60%. The sample covered 53 of California's 58 counties. The sample was selected in proportion to each county's population size. The 5 counties which were not covered in the survey each represents no more than one-tenth of one percent of the state's total population. All panelists were interviewed four times, once every three months. Each respondent was sent a reminder postcard that notified him/her when he/she would be contacted (or re-contacted). Each respondent was also provided a diary to keep track of his/her off-road fuel use. The registration status of each vehicle sampled was determined by matching the sampled vehicles with California's Department of Motor Vehicles' registration file of off-highway vehicles. Based on the matching results, a correction factor was computed to estimate the total number (registered and unregistered vehicles) of off-road vehicles of a particular class. This correction factor was 1 plus the ratio of unregistered

vehicles to registered vehicles. A summary of the survey results are presented in Table 17.

The reported estimate of annual fuel use is the product of the monthly fuel consumption estimates and the monthly usage estimates summed over the year 1989. Compared to other states' and MIC's estimates, California's estimates are among the lowest in this summary of off-road fuel consumption studies. However, the correction factor for unregistered vehicle seems surprisingly high for motorcycles, a ratio of six to one. This correction factor was based on an observation of 521 vehicles of which only 76 could be matched with DMV records. Any problems with this matching process could easily result in an over- or (under-) estimate of the ratio of unregistered vehicles to registered vehicles. Table 17 also shows the resulting estimate of the off-road motorcycle population which is over four and a half times that of the MIC estimates. Clearly, the difference is difficult to account for, short of an overly high correction factor for unregistered vehicles.

Colorado

A mail survey was done of randomly-selected registered off-road vehicles. Unfortunately, documentation of survey results is virtually non-existent. Since no information is available regarding the important factors, such as the number of households surveyed or the response rate, etc., no assessment is made of the survey results. A summary of the reported results are presented in Table 18.

The total number of vehicles was derived based on an assumption that half of all off-highway motorcycles, half of all ATVs, and ninety percent of all snowmobiles are registered. The fuel usage estimates are also very conservative, and in line with those of California.

Table 17. Estimated Number of California Motorcycles and ATVs Used Off-Road for Recreational Purposes and the Corresponding Fuel Use, 1989

	Number Registered	Correction Factor for Unregistered Vehicles	Number of Off-Road Vehicles		Fuel Use (Gallon)	
			California Estimate	MIC Estimate	Annual Fuel Use/Vehicle (Gallon)	Total Annual Fuel Use (Gallon)
Motorcycles: Off-Highway models	207,633	5.9	1,432,668	317,500	44.36	63,552,629
Motorcycles: Highway models	564,949	0	564,949	514,800	6.68	3,772,846
ATVs	76,636	2.5	268,226		28.30	7,590,036

[1] Adjusted to include unregistered vehicles

[2] Motorcycle Statistical Annual, 1989. Motorcycle Industry Council, Inc., California.

Table 18. Estimated Gasoline Consumption of Off-Road Vehicles in Colorado, 1991
(Based on results of the 1991 Colorado off-road vehicle survey)

	Registered Vehicles	Total Vehicles[1]	Annual Fuel Use per Vehicle (Gallon)	Total Annual Fuel Use (Gallon)
Off-Highway Motorcycles	9,389	18,780	27.4	514,360
ATVs	6,260	12,520	49.6	620,560
Snowmobiles	17,658	19,620	81.3	1,595,190

[1] Adjusted to include unregistered vehicles.

Oregon

An off-road vehicle use survey was conducted on randomly-selected registered off-road vehicles. No effort was made to survey non-registered vehicles. A summary of the relevant survey results is present in Table 10.

Not including incomplete responses, the survey response rate was about 70%, which is reasonably good for a voluntary survey. Unfortunately, the results may not be very representative of all off-highway motorcycle owners in that half of the working sample consists of new vehicle owners. These new owners are likely to use their new vehicles more intensively than other owners. This problem is not as pronounced with ATVs in that only 17% of the sampled ATV owners may be new (i.e., owning the vehicle less than a year) (Table 10). These annual fuel consumption estimates illustrate the difference between consumption estimates reported directly by survey respondents and estimates computed by *Days* and *Gallons*. The fact that the average of the product of *Days* and *Gallons* [*Mean(Days*×*Gallons)*] is greater than the product of the averages [*Mean(Days) x Mean(Gallons)*] indicates that *Days* and *Gallons* are positively correlated across individuals. Furthermore, as mentioned earlier, there is no supporting evidence to believe that *Mean(Days* × *Gallons)* is a better estimate than the annual fuel use reported directly by the survey respondents. After an adjustment for recreational use, the estimates for both ATVs and 4x4s in Table 10 are substantially lower than the unadjusted numbers.

Utah

A telephone survey of registered off-road vehicle owners was performed for a 1990 off-road vehicle usage study. This survey contacted over 1,000 owners, of whom 600 completed questionnaires. No attempt was made to estimate the number of unregistered vehicles or to estimate non-recreational use. The survey

specifically asked about the total gallons of fuel purchased for off-road vehicles. The overall fuel use for off-road vehicles is reported to be 331 gallons per household. Unfortunately, tabulations of the survey results did not include average annual fuel consumption by vehicle class. The results of this survey are, therefore, of limited value to this study.

Washington

A telephone survey of 3,460 households was conducted in 1986 regarding off-road recreational vehicle usage in 1985. The method that was used to select telephone numbers is not documented. The sample size within each district was proportional to the population of the counties making up the district. The survey identified 763 households owning one or more off-road vehicles (ORV). The parameters at the state level were estimated by proportionally weighting the survey results by the sampling expansion factors. These estimates together with other relevant statistics are reported in Table 11. Also reported in Table 11 is a confidence range with an unspecified significance level. A comparison with MIC's 1985 estimates of the number of off-road motorcycles and ATVs yields a large difference which is over four times the reported confidence range.

A follow up mail survey was also conducted with the owners identified in the telephone survey. Unfortunately, only 34% of these households returned a completed survey. Only 2% of both dirt bike and ATV owners did not use their vehicles at all in 1985, whereas 14% of dirt bike owners and 25% of ATV owners used their vehicles over one hundred days in 1985. The survey did not include any questions regarding fuel consumption. Results from this mail survey are most likely not representative due to selection bias.

Comparison Summary

Estimates of the annual fuel consumption per off-road motorcycle (or ATV) from four states (California, Colorado, Oregon and Washington) and the MIC are summarized in Table 19. As discussed previously, the MIC estimate was calculated as:

$$\frac{Mean(Days)+Median(Days)}{2} \times \frac{(Means(Dgallons)+Median(Dgallons)}{2} = 76 \text{ gallons per year} \quad (3)$$

Unless it can be proved that *Days* and *Dgallons* are uncorrelated (i.e., *Cov (Days, Dgallons)* = 0), a more accurate estimate of annual fuel use could have been calculated as:

Mean(*Days* × *Dgallons*) or Median(*Days* × *Dgallons*)

or as:

Mean(*Gallons*) or Median(*Gallons*)

where *Days* = the number of days ridden per year off-highway for recreational purposes,

Dgallons = the amount of fuel used per day ridden off-highway for recreational purposes, and

Gallons = the estimated annual fuel used per vehicle ridden off-highway for recreational purposes.

The resulting estimates vary considerably depending on which method is employed. Without the actual survey data, these more accurate estimates of annual fuel use can not be calculated.

Table 19. Comparison of Annual Fuel Use per Off-Highway Motorcycle and ATV
(Based on four State surveys and the MIC survey)

Source	Sample Size	Annual Fuel Use/Vehicle		Total Annual Miles/Vehicle	
		Motorcycles	ATVs	Motorcycles	ATVs
MIC	1,193	76.0	76.0	353	353
California	754	44.4	28.3	-	-
Colorado	?	27.4	49.6	-	-
Oregon	721	89.3	125.6	-	-
Washington	282	-	-	2,700	3,360

The California estimates appear to be carefully developed. A multiple-survey effort with a usage diary is a better method of obtaining annual fuel consumption estimates than using the product of the number of days riding off-highway per year and the amount of fuel used per day. California's estimates are considerably lower than those reported by the MIC.

The Colorado estimates are also reasonably low but are basically undocumented. It is difficult, therefore, to give these estimates much weight in formulating an overall summary measure.

The Oregon estimates are the highest in this review of off-highway vehicle studies. The motorcycle estimate is likely to be biased upwardly because of the large proportion of new motorcycle owners, 50%. The ATV estimate is also quite large but may be reasonably representative in that only 17% of the sampled ATV owners were new owners and that the survey response rate was almost 70%. However, the large proportion of vehicles which were not used for recreational

purposes, 25%, was not properly accounted for in the final estimation, resulting in a large over-estimation of the final state totals.

The Washington survey, which did not collect fuel consumption information, reports very high annual mileage. With a response rate of only 30%, selection bias is likely to be strong. Consequently, the value of this survey is limited for the purpose of our study.

Based on these available estimates, the following combined estimates are formulated. The high and low ranges in Table 20 appear reasonable given the wide variation in available estimates. The subjective weights are based on the above assessments. A higher subjective weight is given to an estimate from an approach that is more reliable for the purpose of our study. Based on these weighted averages of annual fuel use, three sets of estimates are calculated for each vehicle class. One set is based on the low fuel use estimate, one on the high fuel use estimate, and the third one on the average of the low and high estimates. Tables 21 and 22 present the estimated number of vehicles used off-highway at some time for recreational purposes, and the amount of fuel used by motorcycles and ATVs for off-the-road recreational purposes, respectively.

State population estimates of off-highway vehicles also exhibit considerable variation. A summary of these estimates is provided in Table 23. Estimates for both Colorado and Oregon are lower than other states' estimates for the following reason. These state estimates are both based on the number of registered vehicles with no attempt to estimate the number of unregistered vehicles. On the other hand, Arizona, California, and Washington all attempt to estimate the number of unregistered vehicles by means of a survey. The California survey did not have a vehicle registration status question, and instead relied on matching the

Table 20. Subjective Weights and Weighted Average Annual Fuel Consumption per Off-Highway Motorcycle and ATV

	Subjective Weights	
	Low	High
California	75.0%	50%
Oregon	12.5%	25%
MIC	12.5%	25%
Weighted Average Fuel Use Per Vehicle		
Motorcycles	54	64
ATVs	46	65

Department of Motor Vehicles' records. This approach may in part account for the large difference from the corresponding MIC estimate. In any case, the large differences between the state's estimates and the MIC's corresponding estimates for Arizona and Washington are difficult to explain. Even after adjusting the MIC estimates to allow a positive net vehicle migration and to have slower depreciation rates, at most only 30% of these differences may be accounted for. The remaining difference might be attributable to:

1. limitations in states' survey sampling methods, and
2. inaccuracy in MIC's annual retail sales.

Without additional information, it is not possible to resolve the differences between the states' and MIC's estimates at this time. It is therefore recommended that the MIC's estimates continue to be used in estimation of state number of motorcycles and ATVs used for off-highway recreational purposes.

Table 21. Estimated Number of Motorcycles Used off the Road for Recreational Purposes and the Corresponding Fuel Consumption - 1992

State	Number of Vehicles	Fuel Used (Gallon)		
		Low Estimates[1]	Average Estimates[2]	High Estimates[3]
Alabama	27,400	1,479,600	1,616,600	1,753,600
Alaska	6,000	324,000	354,000	384,000
Arizona	25,100	1,355,400	1,480,900	1,606,400
Arkansas	17,600	950,400	1,038,400	1,126,400
California	253,754	13,702,730	14,971,500	16,240,270
Colorado	31,900	1,722,600	1,882,100	2,041,600
Connecticut	18,100	977,400	1,067,900	1,158,400
Delaware	3,308	178,618	195,156	211,695
D. C.	241	13,038	14,246	15,453
Florida	70,517	3,807,897	4,160,480	4,513,063
Georgia	45,500	2,457,000	2,684,500	2,912,000
Hawaii	—[4]	—[4]	—[4]	—[4]
Idaho	24,100	1,301,400	1,421,900	1,542,400
Illinois	45,000	2,430,000	2,655,000	2,880,000
Indiana	30,800	1,663,200	1,817,200	1,971,200
Iowa	16,200	874,800	955,800	1,036,800
Kansas	12,300	664,200	725,700	787,200
Kentucky	19,300	1,042,200	1,138,700	1,235,200
Louisiana	16,800	907,200	991,200	1,075,200
Maine	9,500	513,000	560,500	608,000
Maryland	24,400	1,317,600	1,439,600	1,561,600
Massachusetts	29,300	1,582,200	1,728,700	1,875,200
Michigan	52,500	2,835,000	3,097,500	3,360,000
Minnesota	25,800	1,393,200	1,522,200	1,651,200
Mississippi	10,200	550,800	601,800	652,800
Missouri	22,300	1,204,200	1,315,700	1,427,200

[1] Estimates are based on 54 gallons per vehicle.
[2] Estimates are based on 59 gallons per vehicle.
[3] Estimates are based on 64 gallons per vehicle.
[4] Motorcycle data for Hawaii are not available.

State	Number of Vehicles	Fuel Used (Gallon)		
		Low Estimates[1]	Average Estimates[2]	High Estimates[3]
Montana	14,000	756,000	826,000	896,000
Nebraska	8,300	448,200	489,700	531,200
Nevada	13,396	723,369	790,348	857,326
New	11,400	615,600	672,600	729,600
New Jersey	35,800	1,933,200	2,112,200	2,291,200
New Mexico	14,300	772,200	843,700	915,200
New York	64,300	3,472,200	3,793,700	4,115,200
North	42,800	2,311,200	2,525,200	2,739,200
North Dakota	5,100	275,400	300,900	326,400
Ohio	52,200	2,818,800	3,079,800	3,340,800
Oklahoma	26,100	1,409,400	1,539,900	1,670,400
Oregon	31,223	1,686,028	1842141	1,998,255
Pennsylvania	62,200	3,358,800	3,669,800	3,980,800
Rhode Island	5,000	270,000	295,000	320,000
South	19,200	1,036,800	1,132,800	1,228,800
South Dakota	5,500	297,000	324,500	352,000
Tennessee	32,800	1,771,200	1,935,200	2,099,200
Texas	96,000	5,184,001	5,664,001	6,144,001
Utah	24,300	1,312,200	1,433,700	1,555,200
Vermont	4,100	221,400	241,900	262,400
Virginia	36,200	1,954,800	2,135,800	2,316,800
Washington	50,700	2,737,800	2,991,300	3,244,800
West Virginia	16,700	901,800	985,300	1,068,800
Wisconsin	27,000	1,458,000	1,593,000	1,728,000
Wyoming	7,000	378,000	413,000	448,000
TOTAL	1,543,539	83,351,081	91,068,772	98,786,463

[1] Estimates are based on 54 gallons per vehicle.
[2] Estimates are based on 59 gallons per vehicle.
[3] Estimates are based on 64 gallons per vehicle.

Table 22. Estimated Number of ATVs Used off the Road for Recreational Purposes and the Corresponding Fuel Consumption - 1992

State	Number of Vehicles	Fuel Used (Gallon)		
		Low Estimates[1]	Average Estimates[2]	High Estimates[3]
Alabama	44,764	2,059,165	2,484,427	2,909,690
Alaska	20,270	932,441	1,125,010	1,317,579
Arizona	26,624	1,224,698	1,477,625	1,730,552
Arkansas	55,596	2,557,401	3,085,560	3,613,719
California	137,720	6,335,115	7,643,454	8,951,793
Colorado	16,262	748,040	902,527	1,057,013
Connecticut	10,030	461,392	556,679	651,966
Delaware	3,619	166,490	200,874	235,258
D. C.	0	0	0	0
Florida	45,311	2,084,290	2,514,742	2,945,193
Georgia	50,934	2,342,970	2,826,845	3,310,719
Hawaii	[4]	[4]	[4]	[4]
Idaho	15,430	709,768	856,351	1,002,933
Illinois	29,513	1,357,583	1,637,954	1,918,324
Indiana	30,026	1,381,193	1,666,440	1,951,686
Iowa	16,617	764,378	922,239	1,080,100
Kansas	11,548	531,228	640,938	750,649
Kentucky	29,477	1,355,959	1,635,994	1,916,028
Louisiana	44,764	2,059,165	2,484,427	2,909,690
Maine	15,005	690,242	832,792	975,342
Maryland	15,968	734,535	886,233	1,037,930
Massachusetts	15,727	723,462	872,873	1,022,283
Michigan	68,906	3,169,662	3,824,266	4,478,870
Minnesota	35,159	1,617,295	1,951,302	2,285,308
Mississippi	34,002	1,564,082	1,887,099	2,210,116
Missouri	39,521	1,817,981	2,193,434	2,568,886
Montana	12,026	553,202	667,450	781,698
Nebraska	13,794	634,523	765,565	896,608

[1] Estimates are based on 46 gallons per vehicle.
[2] Estimates are based on 55.5 gallons per vehicle.
[3] Estimates are based on 65 gallons per vehicle.
[4] ATVs data for Hawaii state are not available.

State	Number of Vehicles	Fuel Used (Gallon)		
		Low Estimates[1]	Average Estimates[2]	High Estimates[3]
Nevada	9,073	417,378	503,575	589,773
New Hampshire	11,394	524,141	632,387	740,634
New Jersey	22,869	1,051,973	1,269,228	1,486,483
New Mexico	9,455	434,907	524,725	614,543
New York	63,953	2,941,832	3,549,385	4,156,937
North Carolina	42,639	1,961,410	2,366,484	2,771,557
North Dakota	5,774	265,614	320,469	375,324
Ohio	48,632	2,237,061	2,699,063	3,161,065
Oklahoma	20,634	949,171	1,145,196	1,341,220
Oregon	29,671	1,364,862	1,646,736	1,928,609
Pennsylvania	78,557	3,613,619	4,359,909	5,106,200
Rhode Island	1,525	70,132	84,615	99,099
South Carolina	16,041	737,894	890,285	1,042,676
South Dakota	6,352	292,176	352,516	412,857
Tennessee	50,249	2,311,437	2,788,798	3,266,160
Texas	77,601	3,569,640	4,306,848	5,044,056
Utah	24,128	1,109,883	1,339,098	1,568,313
Vermont	6,419	295,291	356,274	417,258
Virginia	26,735	1,229,823	1,483,808	1,737,793
Washington	26,094	1,200,343	1,448,240	1,696,137
West Virginia	33,782	1,553,967	1,874,895	2,195,823
Wisconsin	31,245	1,437,267	1,734,094	2,030,921
Wyoming	7,337	337,488	407,186	476,885
TOTAL	1,488,772	68,483,569	82,626,914	96,770,256

[1] Estimates are based on 46 gallons per vehicle.
[2] Estimates are based on 55.5 gallons per vehicle.
[3] Estimates are based on 65 gallons per vehicle.

Table 23. Comparison Summary of States' Estimates of Total Number of Off-Highway Motorcycles and ATVs
(Based on State Surveys)

	State Estimate	MIC Estimate	Ratio (State/MIC)
Arizona	198,395	104,400	1.9
California	1,700,894	317,500	5.4
Colorado	31,300	50,200	0.6
Oregon	42,700	67,500	0.6
Washington	269,667	103,900	2.6

4. SNOWMOBILES

4.1 Estimation Procedure

Since 1981, thirty-one states have been submitting their snowmobile registration data to the International Snowmobile Industry Association (ISIA) in response to ISIA's annual registration survey - North American Snowmobile Registration Survey. Table 24 reports snowmobile registration data by state. In this estimation procedure, all snowmobiles are assumed to be used exclusively off-the-road, implying that c_2 in Equation (1) equals 1. Until state-specific information on the percentage of the time when a snowmobile is used for non-recreational purposes becomes available, the factor c_3 (the percentage of the time when a snowmobile is used for recreational purposes) is arbitrarily set at 0.5 for all states. This assumption is likely to be subject to criticism. However, the major purpose of this estimation procedure is to development a quantitative measure to equitably apportion the National Recreational Trails Trust Fund among states. Setting c_3 to a value other than 0.5 to reflect different degrees of non-recreational snowmobile

Table 24. Number of Registered Snowmobiles by States[1]

STATE	Years										
	1981	1982	1983	1984	1986	1987	1988	1989	1990	1991	1992
Alaska	1,102	2,522	1,602	2,522	2,632	3,593	1,812	2,671	2,756	4,427	4,231
California	5,542	5,048	5,120	4,816	5,837	5,729	6,283	6,847	7,989	8,849	9,646
Colorado	12,832	14,087	13,959	13,788	14,250	13,600	14,234	15,060	16,026	17,142	18,396
Connecticut	2,700	2,577	2,266	2,379	3,239	3,667	3,626	3,503	3,062	2,635	2,600
Delaware	290	290	290	290	290	280	263	328	307	290	176
Idaho	19,961	18,552	21,785	20,200	23,000	18,000	20,000	21,024	15,356	21,000	22,790
Illinois	70,822	72,682	69,439	66,863	65,591	60,490	59,163	62,047	60,510	58,891	58,276
Indiana	44,760	46,361	32,037	32,651	23,539	23,695	26,643	19,206	22,941	21,509	18,178
Iowa	60,000	56,000	60,291	65,329	55,091	55,090	49,033	45,000	22,020	22,000	29,300
Maine	51,511	57,178	42,177	47,862	49,722	56,391	57,481	58,148	63,190	61,641	63,471
Maryland	786	896	639	1,200	400	420	450	450	333	235	235
Massachusetts	18,696	23,000	16,500	15,000	15,000	15,000	15,000	22,000	23,110	13,000	8,253
Michigan	368,858	386,391	282,274	271,221	287,524	200,773	206,544	200,854	205,772	202,368	180,340
Minnesota	228,764	220,100	207,564	202,944	202,944	198,212	181,598	192,647	194,339	191,838	192,926
Montana	10,944	14,046	16,074	13,261	16,569	12,068	50,589	50,000	14,500	14,500	11,300
Nebraska	1,500	1,016	1,664	1,858	994	1,095	1,095	918	902	767	828
New Hampshire	26,679	35,490	21,154	29,658	30,586	32,974	38,332	30,000	33,000	32,430	27,330
New Jersey	5,392	4,015	4,109	4,000	6,000	6,000	6,000	2,600	3,641	2,991	3,000
New Mexico	2,543	3,077	5,900	4,500	6,000	6,000	6,000	7,029	1,100	1,246	1,246
New York	86,907	85,639	73,244	67,346	67,346	60,701	54,321	56,172	46,324	51,239	51,723

[1] Data are based on International Snowmobile Industry Association's North American Snowmobile Registration Survey.

STATE	Years										
	1981	1982	1983	1984	1986	1987	1988	1989	1990	1991	1992
North Dakota	14,900	13,660	14,739	10,976	13,532	10,823	6,415	9,361	10,893	8,200	9,200
Ohio	32,045	32,045	24,048	31,971	15,417	6,388	25,456	18,782	17,947	18,040	15,421
Oregon	7,544	7,682	4,113	8,134	7,813	8,597	8,767	9,349	9,533	9,675	10,078
Pennsylvania	55,763	56,459	55,000	47,000	46,700	47,000	46,500	43,785	43,000	39,449	42,354
Rhode Island	400	451	395	395	395	2,700	395	395	432	375	353
South Dakota	4,695	6,986	7,839	9,617	9,066	5,163	6,459	6,433	3,200	4,028	3,480
Utah	14,984	17,016	16,355	11,741	13,480	12,951	11,884	16,481	12,706	14,034	9,683
Vermont	22,223	28,827	19,971	21,288	11,953	19,566	23,573	27,953	33,961	32,762	31,515
Washington	14,194	15,161	14,959	14,959	17,020	15,813	17,922	20,032	17,280	19,631	20,414
Wisconsin	162,600	175,334	159,561	164,124	154,000	145,609	149,839	150,963	151,000	155,632	156,062
Wyoming	9,468	12,715	12,972	12,197	11,136	11,868	13,736	14,958	14,683	14,506	14,208
TOTAL	**1,359,115**	**1,415,031**	**1,207,750**	**1,199,800**	**1,177,066**	**1,060,256**	**1,109,413**	**1,114,996**	**1,051,813**	**1,045,330**	**1,017,013**

[1] Data are based on International Snowmobile Industry Association's North American Snowmobile Registration Survey.

use will not alter the final state distribution unless data on state-specific c_3 are available (i.e., c_3 varies from one state to the next).

In the ISIA survey, participating states are asked to estimate the number of unregistered snowmobiles. In the 1991-1992 survey, four states (California, Colorado, Idaho, and New Hampshire) provided the number of unregistered snowmobiles. The state-specific percentage of unregistered snowmobiles (c_1) ranges from 5% in New Hampshire to 55% in Idaho. ISIA estimated that the national average is 20% using these survey data. For states that did not provide any information on unregistered snowmobiles in ISIA's annual survey, the ISIA estimate of 20% was used to adjust for unregistered snowmobiles. The estimated numbers of snowmobiles used off-highway for recreational purposes by state are based on ISIA's survey results, with one exception (Arizona), and are presented in Table 25. The State of Arizona, based on its two off-highway vehicle surveys, estimated that there were 1,088 snowmobiles ridden off-the-road in 1990. This estimate of 1,088 was used by Arizona State to calculate Arizona's snowmobile recreational fuel use. Arizona has never in the past 13 years reported any snowmobile registration data in the ISIA's annual snowmobile survey. This instance reflects a shortcoming of relying on data from the ISIA survey to estimate numbers of snowmobiles used off-road for recreational purposes -- snowmobile count data are missing for states that are unable or that fail to respond to the ISIA annual survey. Further attempts were made to obtain snowmobile count data by contacting a few state Departments of Transportation and trade associations (e.g., National Sporting Goods Association). Most of the states contacted are unable to provide snowmobile count data because of either no requirement to register snowmobiles, or the absence of a proper procedure to separate snowmobiles from other types of off-road vehicles which are grouped together. Although

Table 25. Estimated Number of Snowmobiles Used for Off-Road Recreational Purposes and the Corresponding Fuel Consumption, 1992
(After adjusted for unregistered snowmobiles)

State	Number of Snowmobiles	Fuel Used (gal.)	Average Fuel Use per Snowmobile (gal.)
Alabama	0	0	0
Alaska	5,077	162,470	32
Arizona	2,610	16,704	6.4
Arkansas	0	0	0
California	11,865	151,867	12.8
Colorado	22,443	430,908	19.2
Connecticut	3,120	59,904	19.2
Delaware	211	2,703	12.8
D. C.	0	0	12.8
Florida	0	0	0
Georgia	0	0	0
Hawaii	0	0	0
Idaho	35,325	904,307	25.6
Illinois	69,931	895,119	12.8
Indiana	21,814	279,214	12.8
Iowa	35,160	450,048	12.8
Kansas	0	0	12.8
Kentucky	0	0	6.4
Louisiana	0	0	0
Maine	76,165	1,949,829	25.6
Maryland	282	3,610	12.8
Massachusetts	9,904	190,149	19.2
Michigan	216,408	4,155,034	19.2
Minnesota	231,511	4,445,015	19.2
Mississippi	0	0	0
Missouri	0	0	6.4
Montana	13,560	347,136	25.6
Nebraska	994	19,077	19.2
Nevada	0	0	19.2
New Hampshire	28,697	734,630	25.6

State	Number of Snowmobiles	Fuel Used (gal.)	Average Fuel Use per Snowmobile (gal.)
New Jersey	3,600	46,080	12.8
New Mexico	1,495	19,139	12.8
New York	62,068	1,588,931	25.6
North Carolina	0	0	6.4
North Dakota	11,040	211,968	19.2
Ohio	18,505	236,867	12.8
Oklahoma	0	0	6.4
Oregon	12,094	309,596	25.6
Pennsylvania	50,825	975,836	19.2
Rhode Island	424	5,422	12.8
South Carolina	0	0	0
South Dakota	4,176	80,179	19.2
Tennessee	0	0	0
Texas	0	0	0
Utah	11,620	297,462	25.6
Vermont	37,818	968,141	25.6
Virginia	0	0	12.8
Washington	24,497	627,118	25.6
West Virginia	0	0	12.8
Wisonsin	187,274	3,595,669	19.2
Wyoming	17,050	436,470	25.6
TOTAL	1,227,563	24,596,602	

[1] Adjusted based on ISIA's usage estimate of 63 gallons per snowmobile.

snowmobile sales data are reported by a few trade associations, they are not available at the state level.

Based on the survey data, the ISIA estimates that the average annual amount of fuel used per snowmobile is 63 gallons. However, to account for the difference in snowmobile usage among states, data on the average annual amount of snowfall are used to derive a set of adjustment factors, ranging from 0 to 5 (Table 26). The adjustment factor of 0 indicates that the amount of snowfall is negligible (such as in Hawaii or Florida), while an adjustment factor of 5 indicates the heaviest amount of snowfall (such as in Alaska). It is recognized that snowmobile usage is more a function of the amount of snow accumulated on the ground than of the amount of snowfall. Since data on state-specific snow accumulation are not readily available, the average annual amount of snowfall is used as a proxy of snow accumulation. The average annual amount of snowfall is estimated from a map of mean annual snow fall. All states that did not report any snowmobile registration data in the ISIA's survey are assumed to have no snowmobile activities, except Arizona.

The estimated annual fuel used by snowmobiles for off-highway recreational purposes is calculated by

$$Gal_{3,j,t} = N_{3,j,t} \times (63\ Gallons \times c_3) \times \zeta_j \qquad (1)$$

where $N_{3,j,t}$= the number of snowmobiles, registered and unregistered, in state j in year t; c_3 (the percentage of the time when a snowmobile is used for recreational purposes) = 0.5, and ζ_j = the adjustment factor for state j in terms of the

Table 26. Average Annual Amount of Snow Fall and the Correction Factors For Snowmobile Usage

State	Mean Annual Snow Fall[1] (in)	Correction Factor	State	Mean Annual Snow Fall[1] (in)	Correction Factor
Alabama	< 8	0	Missouri	8 - 16	1
Alaska	> 96	5	Nebraska	32 - 64	3
Arizona	8 - 16	1	Montana	64 - 96	4
Arkansas	< 8	0	Nevada	32 - 64	3
California	16 - 32	2	New Hampshire	64 - 96	4
Colorado	32 - 64	3	New Jersey	16 - 32	2
Connecticut	32 - 64	3	New Mexico	16 - 32	2
Delaware	8 - 16	2	New York	64 - 96	4
D.C	8 - 16	2	North Carolina	8 - 16	1
Florida	< 8	0	North Dakota	32 - 64	3
Georgia	< 8	0	Ohio	16 - 32	2
Hawaii	< 8	0	Oklahoma	8 - 16	1
Idaho	64 - 96	4	Oregon	64 - 96	4
Illinois	16 - 32	2	Pennsylvania	32 - 64	3
Indiana	16 - 32	2	Rhode Island	16 - 32	2
Iowa	16 - 32	2	South Carolina	< 8	0
Kansas	16 - 32	2	South Dakota	32 - 64	3
Kentucky	8 - 16	1	Tennessee	< 8	0
Louisiana	< 8	0	Texas	< 8	0
Maine	64 - 96	4	Utah	64 - 96	4
Maryland	16 - 32	2	Vermont	64 - 96	4
Massachusett	32 - 64	3	Virginia	16 - 32	2
Michigan	32 - 64	3	Washington	64 - 96	4
Minnesota	32 - 64	3	West Virginia	16 - 32	2
Mississippi	< 8	0	Wisconsin	32 - 64	3
			Wyoming	64 - 96	4

[1] Deduced based on the map of mean annual snow fall published in the "The National Atlas of the United States of America," p. 100. U.S. Department of Interior, Washington, D.C.

difference in the amount of snow fall (Table 26). The resulting estimates are in Table 25.

4.2 Evaluation of States' Estimates of Snowmobile Usage

Eight states conducted their own snowmobile surveys to estimate the numbers of snowmobiles and the corresponding fuel use. They were: Arizona, California, Colorado, Minnesota, North Dakota, Oregon, Utah and Washington. Four of the surveys focused on all off-road vehicles, including snowmobiles, and were discussed in Sections 2.2 and 3.2. These surveys are discussed briefly and their results on snowmobiles are summarized. Surveys specifically for snowmobiles were conducted by the states of Minnesota, North Dakota, Oregon and Washington; and are discussed here in more detail.

Arizona

The State of Arizona conducted two different surveys during 1989-1990 -- one for the winter and one for the summer season. Each survey covered a six month period and contacted 1,000 households using a random dialing procedure that selected a number of telephone numbers in proportion to each county's population size. Based on the survey results, Table 27 presents the population estimates. To avoid double counting, Arizona excluded rented or borrowed vehicles from the estimated numbers of snowmobiles used off-road, as reported in Table 27. No explanations were offered in the report as to why snowmobiles in Arizona were used in the summer months but not in winter months. Although Arizona survey collected information on miles driven by snowmobiles, the reported survey results do not include any usage information by vehicle class.

Table 27. Estimated Number of Snowmobiles Used for Off-Highway in Arizona, 1990

	Estimated Total Snowmobile Population	Estimated Number of Snowmobiles Used Off-road
Based on the Winter Survey	13,315	0
Based on the Summer Survey	9,321	2,175
Survey Average	11,318	1,088
Based on ISIA's Annual Surveys	0	

Source: "The 1990 Arizona Off-Highway Vehicle Survey," College of Public Programs, Arizona State University, prepared for the Arizona Departments of Transportation and Game and Fish and Arizona State Parks Board. January 1991.

California

The State of California randomly selected a sample of 20,394 households to estimate 1989 off-road fuel use. The survey was completed with a response rate of almost 60%. To determine whether the sampled off-highway vehicles were registered, they were matched to California's Department of Motor Vehicles' registration file of off-highway vehicles. Based on the matching results, the ratio of unregistered snowmobiles to registered snowmobiles was seven to one. This ratio was based on an observation of 8 snowmobiles of which only 1 could be matched with DMV records. The total number of snowmobiles in California was estimated as in Table 28. One of the most significant factors contributing to the difference between California's estimates and ISIA's estimates is probably the correction factor for unregistered snowmobiles.

Table 28. Estimates of California Snowmobile Off-Highway Recreational Fuel Use, 1989

	State's Estimates	ISIA's Estimates
Number of Registered Snowmobiles	6,263	6,847
×		
Correction Factor for Unregistered Snowmobiles	7	2,530[1]
=		
Total Number of Snowmobiles	50,104	9,399
×		
Annual Fuel Used per Snowmobile	34.9	63.0
=		
Total Snowmobile Fuel Use	1,750,824	592,137

[1] Number of unregistered snowmobiles reported to the ISIA annual survey by the State of California.

Colorado

A mail survey was done of randomly-selected registered off-road vehicles in Colorado. Since no information is available regarding the important factors, such as the number of households surveyed or the response rate, etc., no assessment is made of the survey results. The State of Colorado estimated that there were a total of 19,620 snowmobiles in Colorado, both registered and unregistered. Each of these snowmobiles, on average, used 81.3 gallons per year, resulting in an estimate of 1,595,190 gallons of fuel used by snowmobiles for off-road recreational purposes (Table 18).

Minnesota

Minnesota's Department of Natural Resources has conducted surveys of snowmobilers since 1983/1984. Data from each survey were collected either by phone or through the mail. The methods that were used to select the sample, the exact sample sizes and the response rates were not documented. Historical gasoline consumption for registered snowmobiles used in Minnesota by Minnesotans is presented in Table 29. The number of unregistered snowmobiles in 1990/1991 use season was estimated at 35% of the number of registered snowmobiles. Furthermore, registered and unregistered snowmobiles were assumed to have identical use levels of 40.8 gallons per year, resulting in a total of 10,566,381 gallons of fuel used by snowmobiles for off-highway recreational purposes.

Table 29. Gas Consumption of Registered Snowmobiles Used in Minnesota by Minnesotans[1], [2]

Year	Fuel Use/ Snowmobile	×	No. Registered Snowmobiles	=	Total Fuel Use
84-85	20.5	×	203,000	=	4,161,500
85-86	31.9	×	181,000	=	5,773,900
86-87	18.6	×	170,000	=	3,162,000
88-89	51.0	×	184,000	=	9,384,000
89-90	36.4	×	184,000	=	6,697,600
90-91	39.8	×	191,715	=	7,630,257

[1] Based on Table 1 of "Gasoline Consumption by Snowmobiles Within Minnesota" by J.C. Vlaming, D. H. Anderson, and G. Flekke, University of Minnesota. February, 1992.

[2] No survey was conducted for the 1987/1988 use season.

North Dakota

A mail survey of randomly-selected 1,127 registered snowmobile owners was conducted in North Dakota. Of these, 647 completed questionnaires, yielding a response rate of 58%. Survey participants were contacted three times. First, the questionnaire was mailed to all 1,127 sampled snowmobile owners. Approximately 7 days after the questionnaire was mailed, a thank-you/reminder postcard was sent. Finally, 2 to 3 weeks later, another copy of the questionnaire was sent to all non-respondents.

Twenty-four percent of the respondents did not purchase any fuel to operate their snowmobiles in 1991, while 3.1% purchased more than 300 gallons. The reported fuel purchase did not include gasoline used for tow vehicles. The average snowmobile fuel use per household was estimated at 65.8 gallons in 1991, and there were 1.9 snowmobiles per household. The total amount of fuel used by snowmobiles in North Dakota for off-road recreational purposes is estimated as:

Number of registered snowmobiles × *annual fuel used per vehicle*

= 8,820 × (65.8÷1.9) = 305,172 gallons.

North Dakota's estimates of total snowmobile fuel use are substantially lower than estimates based on ISIA's survey results or ORNL's estimates.

Oregon

Oregon's Department of Transportation commissioned a snowmobile survey in the spring of 1990 to estimate snowmobile gasoline consumption. From the Motor Vehicle Division's snowmobile registration file of 18,037 licenses, a sample

of 677 snowmobile license numbers were randomly selected. Of these, 513 completed questionnaires were obtained, resulting in a response rate of 76%.

Ninety-five percent of the sampled snowmobiles were primarily used for recreational purposes. For each respondent, the annual fuel consumption was derived as the product of the number of days in a year that the snowmobile was used for recreational purposes and the amount of fuel used on a typical day of recreational use. The average annual fuel used for recreational purposes per sampled snowmobile was 113.9 gallons with a standard error of 3.3[2]. The total amount of fuel used by snowmobiles licensed in Oregon was estimated by the state to be 18,037 × 113.9 = 2,054,414 gallons, with a 95% confidence interval of 1,933,680 to 2,175,148. The average difference between the estimated annual fuel use reported directly by the survey respondents and the derived annual fuel use is -3.6 gallons (± a standard error of 9), indicating that the difference is not significantly different from zero. In this calculation, the State failed to eliminate 5% of the State's snowmobiles that were not used primarily for recreational purposes. The major factor contributing to the difference between Oregon's estimates and ORNL's estimates is the discrepancy in the number of snowmobiles registered in Oregon. Oregon's response to the 1990 ISIA's annual snowmobile survey indicated that there were 9,675 snowmobiles registered in Oregon while the snowmobile fuel consumption estimates are based on a snowmobile registration of 18,037 - a difference difficult to explain.

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[2] Bodenroeder, P., Berg, H., and McCracken, M. "Annual Gasoline Consumption of Snowmobiles Licensed in Oregon 1989-1990," Oregon State University. Prepared for the Oregon Department of Transportation, July 1990.

Washington

Since 1971, the Washington State Department of Licensing and the Parks and Recreation Commission have conducted numerous snowmobile studies to determine snowmobile use, snowmobile facility needs, and the amount of fuel tax to be refunded to the snowmobile program. The 1987-1988 study surveyed all 18,200 snowmobile users registered in the 1987-1988 season. A total of 4,651 usable survey forms were received, resulting in a response rate of 25.5%. The average number of days that one went snowmobiling was 15.4 days in a winter[3]. The survey estimated that each snowmobile consumed 72.4 gallons in 1988. This estimate is slightly higher than that of ISIA's estimate but is in close proximity. Table 30 provides a comparison of states' snowmobile fuel use estimates.

Table 30. Comparison of States' Snowmobile Fuel Use Estimates
(Based on four State surveys and the ISIA survey)

Source	Average Fuel Use per Snowmobile
ISIA	63
California	35
North Dakota	35
Oregon	114
Minnesota	41
Washington	72

[3] "1988 Snowmobile Study," Washington State Parks and Recreation Commission, Olympia, Washington.

5. CONCLUDING REMARKS

The 1991 ISTEA established a National Recreational Trails Funding Program and the National Recreational Trails Trust Fund to redirect tax revenues generated from the sales of motor fuel used for off-highway recreational purposes to recreational trail and facility improvements. The major challenge in accomplishing this goal is to determine how the amounts transfered to the Trails Trust Fund can be apportioned *equitably* to individual states. Technically, each state should receive an amount that equals the tax revenues generated by the sales of motor vehicle fuel sold in that state for off-highway recreational purposes. Unfortunately, this type of information is unavailable. As a result, the FHWA was charged with the development of estimates of the fuel used in each *state* for off-highway recreational purposes. These estimates will then be used to apportion the Trails Trust Fund to individual states. This technical memorandum documents the estimation procedures.

Two options are available to develop the state distribution to "share" the total tax revenue generated from the sales of motor vehicle fuel used for off-highway recreation. The first one is to rely on the individual states to submit their annual estimates of off-highway recreational fuel use. The advantage of this option is that individual states could devote more resources to this activity, and can receive more cooperation in obtaining the data, than FHWA could. As a result, individual states might be able to produce more reliable estimates than FHWA could. However, this option has three potential drawbacks. First, individual states have a great incentive to over-estimate their off-highway recreational fuel use. Second, the compatibility among methods that the states use to estimate off-highway recreational fuel use becomes an enormous issue in trying to apportion the Trust Fund equitably. Third, not every state submits the required estimate. In the

1992-1993 period, only twenty-three states did, and some of the estimates are for 1987 while others are for 1989 or 1990 (Table 7). Consequently, an estimation procedure would need to be developed for the remaining 22 states that failed to submit data, adding further complexity to the compatibility issue.

To overcome the disadvantages of the first option, a second option is to "standardize" the estimation procedure and develop a **common** tool which can objectively apportion the National Recreational Trails Trust Funds on an annual basis. Two features of this option are that: (1) individual state shares of the total Trust Funds are developed using a uniform approach, and (2) data needed for the estimation purpose are publicly available and easily obtainable so that estimates for all subsequent years can be easily generated. It is these two factors that govern the development of ORNL's estimation procedure discussed in this report. It is also due to these two factors that ORNL's estimates are used instead of individual states' estimates.

Vehicles included in this study are: light trucks, motorcycles, ATVs, and snowmobiles. "Light trucks" include pickups, vans, minivans, and utility vehicles with a maximum gross vehicle weight less than or equal to 10,000 pounds. The estimated total number of light trucks used for off-highway recreation is defined as the total number of "full light truck equivalents." That is, if 30% of the total annual miles driven by a light truck is for off-highway recreation, then this light truck is counted as 0.30 of a full vehicle equivalent.

The major data source in estimating the light trucks' total fuel used for off-highway recreation is the Truck Inventory and Use Survey (TIUS). Although TIUS did not explicitly collect data on the percentage of the annual mileage that a vehicle was used off-the-road for recreational purposes, it did ask the respondents

to report the average percentage of the annual miles that the vehicle was operated off-the-road, and the percentage of the miles used for personal use. The product of these two percentages is taken to be a proxy for the probability that a truck will be used off-the-road for recreation. The state-specific probabilities are generated from the TIUS data and are used, in conjunction with the truck registration data[4], to estimated the number of "full light truck equivalents" used in each state for off-highway recreation. The percent of annual miles traveled off-the-road for recreation is estimated by the weighted average product of the percentage of the miles that a truck was used off-the-road and the percentage of the miles that it was used for personal purposes, taking into account the annual miles driven by this truck. The state-specific total number of miles traveled off-the-road for recreation is then converted to the amount of fuel consumed by using the average on-road fuel economy of 2-axle 4-tire trucks[5] discounted by 0.9 for the difference between the on-road and the off-road fuel economies.

In the cases of motorcycles, ATVs and snowmobiles, data are considerably sparser than that of light trucks. Estimates of motorcycle and ATV fuel used for off-highway recreation are largely based on vehicle population estimates compiled annually by the Motorcycle Industry Council (MIC) and vehicle usage data collected in two state surveys (California and Oregon.) Although the MIC has conducted periodic surveys of motorcycle and ATV annual usage, the information is, unfortunately, considered proprietary and only limited access is allowed.

Due to lack of more detailed data, it is assumed that whenever motorcycles are used off-the-road, they are done so for recreational purposes. A recent MIC

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4 Compiled by the R. L. Polk and Company.

5 Reported in the Table VM-1 of the *Highway Statistics*.

survey on ATVs provides an estimate of the percentage of ATV off-road riding for utility purposes, which allows better estimates of the number of ATVs used off-the-road for recreation.

Unlike light trucks, there is no survey of motorcycles and ATVs that provides consistent estimates of annual fuel use by state. In addition to the MIC's periodic surveys, there are six state surveys conducted to estimate the number of motorcycles and ATVs used off-road, and the corresponding fuel consumption. The six states are: Arizona, California, Colorado, Oregon, Utah and Washington. Several options are considered to estimate annual fuel use. Since every survey has its strengths and limitations, we synthesize all available estimates. After a detailed evaluation of MIC survey and individual state surveys, a set of weighting factors is subjectively determined. A higher subjective weight is given to a usage estimate from an approach that is more reliable for the purpose of our study. Based on the weighted averages of annual fuel use, three sets of fuel usage estimates are calculated for motorcycles and ATVs, respectively. One set is based on the low fuel use estimate, one on the high fuel use estimate and the third one on the average of the low and high estimates.

The International Snowmobile Industry Association (ISIA) has been conducting its annual registration survey since 1981. Thirty-one states participated in the survey. In this estimation procedure, all snowmobiles are assumed to be used exclusively off-the-road and the percentage of time that a snowmobile is used for recreational purposes is arbitrarily set at 0.5 for all states. Until state-specific information on the percentage of time that a snowmobile is used for non-recreational purposes becomes available, setting this value to 0.5 is inconsequential since the objective of this estimation procedure is to develop state *shares* so that the Trails Trust Fund can be equitably apportioned among states.

Based on the ISIA's survey data, the estimated annual fuel use per snowmobile is 63 gallons. To account for the difference in snowmobile usage among states, data on the average annual amount of snowfall are used to derived a set of adjustment factors -- 0 being a negligible amount of snowfall and 5 being the heaviest amount of snowfall. However, it is recognized that snowmobile usage is more a function of the amount of snow accumulated on the ground than of the amount of snowfall. Under the circumstance where data on snow accumulation are lacking, the amount of average annual snow fall is used as a proxy.

Table 31 presents the estimated state shares of total fuel used for off-highway recreational purposes. Estimates of motorcycle and ATV fuel used off-road for recreation are based on the average of the low and high fuel use estimates.

Table 31. Estimated Fuel Used for Off-Highway Recreation by State, 1992
(Gallons)

State	Light Truck	Motorcycle[1]	ATV[2]	Snowmobile	Total	*State Share*
Alabama	29,612,540	1,616,600	2,484,427	0	33,713,567	*2.3*
Alaska	4,222,881	354,000	1,125,010	162,470	5,864,361	*0.4*
Arizona	34,863,870	1,480,900	1,477,625	16,704	37,839,099	*2.6*
Arkansas	31,214,200	1,038,400	3,085,560	0	35,338,160	*2.4*
California	87,501,790	14,971,500	7,643,454	151,867	110,268,611	*7.6*
Colorado	35,747,660	1,882,100	902,527	430,908	38,963,195	*2.7*
Connecticut	13,287,790	1,067,900	556,679	59,904	14,972,273	*1.0*
Delaware	1,926,005	195,156	200,874	2,703	2,324,738	*0.2*
D. C.	384,639	14,246	0	0	398,885	*0.0*
Florida	63,415,330	4,160,480	2,514,742	0	70,090,552	*4.8*
Georgia	34,257,590	2,684,500	2,826,845	0	39,768,935	*2.7*
Hawaii	6,740,744	na	na	0	6,740,744	*0.5*
Idaho	14,040,740	1,421,900	856,351	904,307	17,223,298	*1.2*
Illinois	30,495,210	2,655,000	1,637,954	895,119	35,683,283	*2.5*
Indiana	23,437,450	1,817,200	1,666,440	279,214	27,200,304	*1.9*
Iowa	10,331,750	955,800	922,239	450,048	12,659,837	*0.9*
Kansas	17,297,930	725,700	640,938	0	18,664,568	*1.3*
Kentucky	23,676,820	1,138,700	1,635,994	0	26,451,514	*1.8*
Louisiana	31,259,590	991,200	2,484,427	0	34,735,217	*2.4*
Maine	9,416,821	560,500	832,792	1,949,829	12,759,942	*0.9*
Maryland	17,644,210	1,439,600	886,233	3,610	19,973,653	*1.4*
Massachusetts	11,222,520	1,728,700	872,873	190,149	14,014,242	*1.0*
Michigan	47,067,690	3,097,500	3,824,266	4,155,034	58,144,490	*4.0*
Minnesota	16,813,700	1,522,200	1,951,302	4,445,015	24,732,217	*1.7*
Mississippi	19,719,110	601,800	1,887,099	0	22,208,009	*1.5*
Missouri	33,165,950	1,315,700	2,193,434	0	36,675,084	*2.5*
Montana	12,816,880	826,000	667,450	347,136	14,657,466	*1.0*

State	Light Truck	Motorcycle[1]	ATV[2]	Snowmobile	Total	*State Share*
Nebraska	9,330,951	489,700	765,565	19,077	10,605,293	*0.7%*
Nevada	7,933,052	790,348	503,575	0	9,226,975	*0.6%*
New Hampshire	7,635,064	672,600	632,387	734,630	9,674,681	*0.7%*
New Jersey	28,299,860	2,112,200	1,269,228	46,080	31,727,368	*2.2%*
New Mexico	34,684,160	843,700	524,725	19,139	36,071,724	*2.5%*
New York	27,404,280	3,793,700	3,549,385	1,588,931	36,336,296	*2.5%*
North Carolina	29,539,790	2,525,200	2,366,484	0	34,431,484	*2.4%*
North Dakota	6,369,731	300,900	320,469	211,968	7,203,068	*0.5%*
Ohio	28,777,470	3,079,800	2,699,063	236,867	34,793,200	*2.4%*
Oklahoma	35,621,720	1,539,900	1,145,196	0	38,306,816	*2.6%*
Oregon	17,417,560	1,842,141	1,646,736	309,596	21,216,033	*1.5%*
Pennsylvania	42,419,390	3,669,800	4,359,909	975,836	51,424,935	*3.5%*
Rhode Island	3,919,044	295,000	84,615	5,422	4,304,081	*0.3%*
South Carolina	24,611,430	1,132,800	890,285	0	26,634,515	*1.8%*
South Dakota	6,678,720	324,500	352,516	80,179	7,435,915	*0.5%*
Tennessee	30,990,840	1,935,200	2,788,798	0	35,714,838	*2.5%*
Texas	129,026,500	5,664,001	4,306,848	0	138,997,349	*9.6%*
Utah	13,153,290	1,433,700	1,339,098	297,462	16,223,550	*1.1%*
Vermont	4,011,685	241,900	356,274	968,141	5,578,000	*0.4%*
Virginia	31,831,730	2,135,800	1,483,808	0	35,451,338	*2.4%*
Washington	23,274,490	2,991,300	1,448,240	627,118	28,341,148	*2.0%*
West Virginia	21,492,660	985,300	1,874,895	0	24,352,855	*1.7%*
Wisonsin	18,604,520	1,593,000	1,734,094	3,595,669	25,527,283	*1.8%*
Wyoming	9,516,966	413,000	407,186	436,470	10,773,622	*0.7%*
TOTAL	1,254,126,323	91,068,772	82,626,914	24,596,602	1,452,418,611	*100.0%*

[1] Estimates are based on an annual fuel use of 59 gallons per motorcycle.
[2] Estimates are based on an annual fuel use of 55.5 gallons per ATV.

APPENDIX A

COMPUTER PROGRAM ESTIMATING OFF-HIGHWAY RECREATIONAL FUEL USE

The main objective of this program is to estimate the number of vehicles used for off-the-road recreational purposes and the corresponding fuel use. Three categories of vehicles are included in this program: light trucks, motorcycles and all terrain vehicles (ATVs), and snowmobiles. This program allows the user to update/edit the data input files, execute separate estimation models -- one for each type of vehicle, and display the output files. A simple menu-driven interface is provided in this program to accomplish these tasks. Currently, this program is named ***GO***. All of the input and output files listed below are manipulated by this program.

For each class of vehicles, the future vehicle population is forecasted by using an exponential smoothing based on past vehicle population data. This forecasting feature may be turned off by selecting the default menu setting under which vehicle population is assumed to remain constant. Estimates of fuel consumption are then computed for the projected vehicle population based on annual fuel usage estimates and other correction factors. The two basic tasks that require input from the model user are annually updating the data, and executing the model. These two tasks are explained in the following section for each of the three different vehicle classes. This program also allows the model user to alter model parameters and assumptions, such as fuel use level, and correction factor for unregistered vehicles.

1. LIGHT TRUCKS

1.1 Updating Data Sources

The file *PICKUP1.DAT* contains light truck statistics on off-the-road usage, by state, based on the 1987 Truck Inventory Use Survey (TIUS). This file should updated when the new TIUS data become available. The file *PICKUP2.DAT* contains national totals of the number of trucks, the average fuel economy and the average fuel consumption of 2-axle 4-tire trucks, and the annual miles driven by 2-axle 4-tire trucks. This file needs to be updated annually.

1.2 Executing the Model

The model user may investigate the effect of an exponential smoothing forecast relative to a "no change" forecast. The model setting menu provides a "Yes/No" switch for employing an exponential smoothing forecast. A "Yes" setting uses the exponential smoothing forecast while a "No" setting yields a "no change" forecast.

2. MOTORCYCLES & ATVS

2.1 Updating Data Sources

Two files, *MCATV.DAT* and *ATV.DAT*, contain population estimates of motorcycles and ATVs. The file *MCATV.DAT* has time series data of motorcycles and ATVs combined, by state, from 1984 to 1991. The file *ATV.DAT* contains population estimates of only ATVs, by state, for the year 1991. That was the year when motorcycle and ATV estimates were reported separately for the first time by

the Motorcycle Industry Council (MIC). The time series data of the combined vehicle population of motorcycles and ATVS are used to forecast the future combined population. However, it is important to estimate the ATV population separately for two reasons. First, fuel use by motorcycles is different from fuel use by ATVs. Second, the percentage of the time that motorcycles are used for recreational purposes is different from that of ATVs. These two files, *MCATV.DAT* and *ATV.DAT*, should be updated annually.

2.2 Executing the Model

The estimation model in this program allows the user to consider more than one set of vehicle usage estimates at the state level. For example, the sensitivity of a state's shares of gasoline consumption with respect to high/low usage estimates may be easily evaluated with this model. Currently, two different sets of total fuel use estimates are included based on reasonably conservative high/low estimates of individual vehicle's fuel use. Estimates based on the low fuel use estimates are denoted as Method 1, and estimates based on the high estimate as Method 2. The model-setting menu allows the user to indicate which method to use. The program will allow additional sets of fuel usage estimates to be input and evaluated. As mentioned in Section 1.2, control of the exponential smoothing option is provided under the model setting menu.

3. SNOWMOBILE

3.1 Updating Data Sources

The file *SNOW1.DAT* contains estimates of snowmobile population, by state, based on snowmobile registration data provided by the International

Snowmobile Industry Association (ISIA). This file should be updated annually. The file *SNOW2.DAT* contains the estimated percentage of unregistered vehicles at the state level, annual fuel consumption per vehicle, and correction factors for the amount of snow fall (scale of 0-9). The percentage of unregistered vehicles is based on the ISIA's annual survey of snowmobile registration. The regional correction factor for the amount of snow fall is a rough attempt at adjusting for state variations in snow availability.

3.2 Executing the Model

As with motorcycles and ATVs, control of the exponential smoothing option is provided under the model setting menu. Assumptions regarding the key factors, such as the percentage of unregistered snowmobiles, annual fuel usage, and snow fall are contained in the data file *SNOW2.DAT*. The UPDATE SNOWMOBILE DATA/ EDIT SNOWMOBILE USAGE DATA menu may be used to alter these estimates.

Disk Contents

MAIN PROGRAM

GO	EXE	36750

AUXILIARY PROGRAMS CALLED BY *GO*

ALLN	EXE	110424
MCYCLE	EXE	58748
PICKUP0	EXE	42468
SNOW0	EXE	39407
LIST	COM	8191

DATA INPUT FILES

ATV	DAT	1378	- ATV Population by state
ATVCRT	DAT	1406	- ATV Non recreational usage correction factor
GAS	DAT	3049	- Motorcycle & ATV annual gasoline usage estimates
MCATV	DAT	5536	- Motorcycle & ATV combined population by state
METHODS	DAT	258	- Model default settings
PICKUP1	DAT	3088	- 1987 TIUS off road usage estimates
PICKUP2	DAT	1286	- National annual estimates of Truck population & fuel usage
SNOW1	DAT	5673	- Snowmobile population by state
SNOW2	DAT	2710	- Snowmobile gasoline usage estimates

MOTOR	OUT	4228	- Motorcycle population & gasoline usage estimates
PICKUP	OUT	2613	- Off road truck population & gasoline usage estimates
SNOW	OUT	2575	- Snowmobile population & gasoline usage estimates
TOTALGAL	OUT	4921	- Total gallons summary
TOTALNUM	OUT	4187	- Total number of vehicles summary

SOURCE CODE FILES

GO	BLD
MCYCLE	BLD
PICKUP0	BLD
SNOW0	BLD
ALLN	FOR

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