

A SURVEY OF VEHICLES USING STUDED, SMOOTH,
OR SNOW TIRES IN MICHIGAN

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MICHIGAN DEPARTMENT OF STATE HIGHWAYS

A SURVEY OF VEHICLES USING STUDED, SMOOTH,
OR SNOW TIRES IN MICHIGAN

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Research Laboratory Section
Testing and Research Division
Research Project 69 G-173
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Michigan State Highway Commission
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Researchers studying pavement friction are aware that the ASTM Standard Pavement Test Tire does not have characteristics identical to conventional automobile tires. However, no one tire could precisely represent the wide variety of tires rolling over Michigan highways. The millions of vehicles using Michigan highways travel on tires of various tread designs, materials, structural types, and states of wear. In order to obtain data so that we might intelligently apply skid test measurements, it was believed that we should learn something of the variation among tires now in use. Therefore, it was decided to conduct a statewide survey of vehicle tire use with tires categorized as: 1) smooth tires (tires with 2/32 in. or less of tread remaining), 2) studded tires, and 3) snow tires.

A survey of vehicles using studded tires had been made by the Research Laboratory during winter 1969-70. Samples for that survey were proportionally allocated, based upon county vehicle registration data. Data from that survey were used to develop a more efficient sampling plan, described in Appendix A, for use in winter 1970-71. Although the plan was developed primarily as a means of estimating tire stud use, it was also used to estimate proportions of vehicles with smooth tires and with snow tires. The sample consisted of 27,025 vehicles, allocated by counties as listed in Table 1. The survey began on January 11, 1971 and extended through February 19.

Only vehicles with Michigan license plates were counted in the survey; State-owned vehicles were not counted nor were trucks other than pickup and panel trucks. After selecting a site, a "cluster" containing a predetermined number of vehicles was surveyed in the order of their physical location. That is, once the cluster was selected, there was no choosing among vehicles, they were inspected in order. Sites were primarily parking lots, but in smaller towns vehicles parked on streets were surveyed.

Table 1 is an alphabetical listing of counties showing numbers of vehicles surveyed, proportions of vehicles with studs, and axle location of studded tires. Table 2 gives the same information but is separated by District, Table 3 relates studded tire use to type of vehicle, and Table 4 lists counties in decreasing order of studded tire use. Figure 1 is a map of the State showing tire stud use by counties. Table 5 compares tire stud survey results for this year and last, Table 6 lists the precision of the estimated proportion for each county.

Tables 7 and 8 show data for snow tires and for smooth tires. Since 1971 was the first year for surveying snow tires and smooth tires, no past year comparisons are available. Tire studs are permitted on vehicles in Michigan from November 1 to May 1 and snow tires are generally used only during those months, thus the results of this survey are valid for the same period.

The Statewide average proportion of vehicles using studded tires increased from about 12 percent in 1969-70 to 15.2 percent in 1970-71. More significantly perhaps, is the fact that the number of vehicles having tire studs in 1970-71 increased over 27 percent. The precision of this estimated proportion is within a fraction of 1 percent, at the 95 percent confidence level.

STUDED TIRE USAGE IN MICHIGAN,
WINTER 1970-71

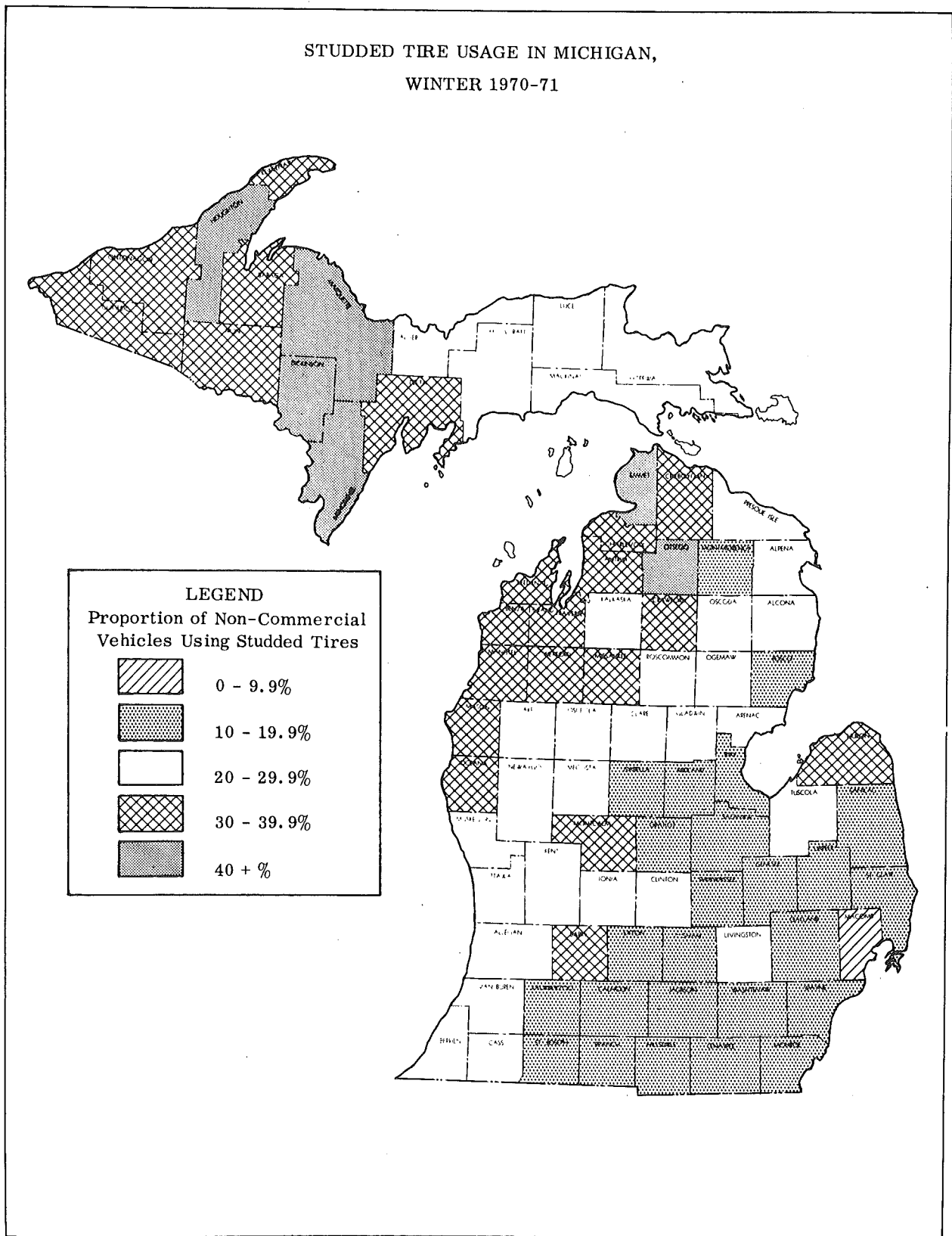


Figure 1. Studded tire usage in Michigan, winter 1970-1971.

TABLE 1
WINTER, 1970-1971 STUDDED TIRE SURVEY BY COUNTIES

County	No. of Vehicles	Percent of Vehicles			
		Without Studs	With Studs on Front Only	With Studs on Rear Only	With Studs on Front and Rear
Alcona	100	72.00	0	28.00	0
Alger	125	73.60	0	26.40	0
Allegan	400	73.00	0	27.00	0
Alpena	200	76.00	0	23.50	0.5
Antrim	100	68.00	0	31.00	1
Arenac	100	73.00	0	27.00	0
Baraga	100	69.00	0	30.00	1
Barry	200	63.50	0	36.00	0.5
Bay	700	83.70	0	16.30	0
Benzie	100	62.00	0	37.00	1
Berrien	1000	78.60	0	21.40	0
Branch	200	88.00	0	12.00	0
Calhoun	800	87.75	0	12.25	0
Cass	100	76.00	0	24.00	0
Charlevoix	100	69.00	0	31.00	0
Cheboygan	100	64.00	0	36.00	0
Chippewa	200	71.50	0	28.50	0
Clare	100	79.00	0	21.00	0
Clinton	200	78.00	0	22.00	0
Crawford	100	65.00	0	35.00	0
Delta	200	68.00	0	31.50	0.5
Dickinson	100	51.00	0	49.00	0
Eaton	300	89.70	0	10.30	0
Emmet	100	60.00	0	40.00	0
Genesee	800	82.875	0	17.125	0
Gladwin	100	73.00	0	27.00	0
Gogebic	100	65.00	0	35.00	0
Grand Traverse	200	65.50	0	34.50	0
Gratiot	200	85.00	0	15.00	0
Hillsdale	200	83.00	0	17.00	0
Houghton	200	54.50	0	45.50	0
Huron	200	68.00	0	32.00	0
Ingham	1200	86.70	0	13.30	0
Ionia	200	79.00	0	21.00	0
Iosco	100	81.00	0	19.00	0
Iron	100	68.00	0	32.00	0
Isabella	200	83.00	0	17.00	0
Jackson	600	80.20	0	19.80	0
Kalamazoo	1100	85.10	0	14.90	0
Kalkaska	100	73.00	0	27.00	0
Kent	1500	78.90	0	21.00	0.1
Keweenaw	100	63.00	0	37.00	0
Lake	100	80.00	0	20.00	0
Lapeer	200	87.00	0	13.00	0
Leelanau	100	62.00	0	37.00	1

TABLE 1 (Cont.)
WINTER, 1970-1971 STUDDED TIRE SURVEY BY COUNTIES

County	No. of Vehicles	Percent of Vehicles			
		Without Studs	With Studs on Front Only	With Studs on Rear Only	With Studs on Front and Rear
Lenawee	500	85.80	0	14.20	0
Livingston	300	79.30	0.7	20.00	0
Luce	100	73.00	0	27.00	0
Mackinac	100	73.00	0	27.00	0
Macomb	1000	92.30	0	7.70	0
Manistee	100	65.00	0	34.00	1
Marquette	300	58.40	0.3	41.30	0
Mason	100	67.00	0	33.00	0
Mecosta	100	75.00	0	25.00	0
Menominee	100	59.00	0	41.00	0
Midland	400	78.25	0	21.50	0.25
Missaukee	100	65.00	0	35.00	0
Monroe	600	85.70	0	14.10	0.2
Montcalm	200	68.50	0	31.50	0
Montmorency	100	84.00	0	16.00	0
Muskegon	900	75.60	0	25.20	0.2
Newaygo	200	74.00	0	26.00	0
Oakland	1200	87.9	0.1	11.90	0.1
Oceana	100	64.00	1	35.00	0
Ogemaw	100	76.00	0	23.00	1
Ontonagon	100	65.00	0	35.00	0
Osceola	100	75.00	0	25.00	0
Oscoda	100	75.00	0	25.00	0
Otsego	100	56.00	0	44.00	0
Ottawa	700	75.40	0	24.60	0
Presque Isle	100	73.00	0	27.00	0
Roscommon	100	79.00	0	21.00	0
Saginaw	900	85.90	0	14.10	0
Sanilac	200	89.00	0	11.00	0
Schoolcraft	100	74.00	0	26.00	0
Shiawassee	300	85.70	0	14.30	0
St. Clair	700	89.60	0	10.40	0
St. Joseph	300	86.30	0	13.70	0
Tuscola	200	77.50	0	22.50	0
Van Buren	300	75.30	0	24.70	0
Washtenaw	1200	88.25	0	11.75	0
Wayne	1500	90.00	0	10.00	0
Wexford	100	66.00	0	33.00	1

TABLE 2
WINTER, 1970-1971 STUDDED TIRE SURVEY BY DISTRICTS

District	No. of Vehicles	Percent of Vehicles			
		Without Studs	With Studs on Front Only	With Studs on Rear Only	With Studs on Front and Rear
1	1200	60.42	0.08	39.42	0.08
2	825	71.64	0.00	28.24	0.12
3	1400	68.60	0.00	31.00	0.40
4	1300	72.08	0.00	27.77	0.15
5	4500	78.40	0.02	21.50	0.08
6	4100	82.44	0.00	17.54	0.02
7	4400	81.34	0.00	18.64	0.02
8	4300	85.62	0.05	14.33	0.00
9	2900	89.21	0.03	10.73	0.03
10	2100	88.76	0.00	11.19	0.05
Total	27025	80.60	0.02	19.32	0.06

TABLE 3
WINTER, 1970-1971 STUDDED TIRE SURVEY BY VEHICLE TYPES

Vehicle		Percent of Vehicles			
Type	No.	None	Front	Rear	Front and Rear
Passenger car	25767	80.5	0.0	19.5	0.0
Pickup & panel trucks	1082	81.7	0.0	18.3	0.0
4 wheel drive	176	87.5	0.0	4.5	8.0

TABLE 4
PERCENT OF VEHICLES USING STUDDED TIRES BY COUNTIES

County	Percent	County	Percent	County	Percent
Dickinson	49.00	Alcona	28.00	Livingston	20.70
Houghton	45.50	Allegan	27.00	Lake	20.00
Otsego	44.00	Arenac	27.00	Jackson	19.80
Marquette	41.67	Gladwin	27.00	Iosco	19.00
Menominee	41.00	Kalkaska	27.00	Genesee	17.13
Emmet	40.00	Luce	27.00	Hillsdale	17.00
Benzie	38.00	Mackinac	27.00	Isabella	17.00
Leelanau	38.00	Presque Isle	27.00	Bay	16.30
Keweenaw	37.00	Alger	26.40	Montmorency	16.00
Barry	36.50	Newaygo	26.00	Gratiot	15.00
Cheboygan	36.00	Schoolcraft	26.00	Kalamazoo	14.90
Oceana	36.00	Muskegon	25.40	Monroe	14.30
Crawford	35.00	Mecosta	25.00	Shiawassee	14.30
Gogebic	35.00	Osceola	25.00	Lenawee	14.20
Manistee	35.00	Oscoda	25.00	Saginaw	14.10
Missaukee	35.00	Van Buren	24.70	St. Joseph	13.70
Ontonagon	35.00	Ottawa	24.60	Ingham	13.30
Grand Traverse	34.50	Alpena	24.00	Lapeer	13.00
Wexford	34.00	Cass	24.00	Calhoun	12.25
Mason	33.00	Ogemaw	24.00	Oakland	12.10
Antrim	32.00	Tuscola	22.50	Branch	12.00
Delta	32.00	Clinton	22.00	Washtenaw	11.75
Huron	32.00	Midland	21.75	Sanilac	11.00
Iron	32.00	Berrien	21.40	St. Clair	10.40
Montcalm	31.50	Kent	21.10	Eaton	10.30
Baraga	31.00	Clare	21.00	Wayne	10.00
Charlevoix	31.00	Ionia	21.00	Macomb	7.70
Chippewa	28.50	Roscommon	21.00		

TABLE 5
COMPARISON OF 1969-1970 AND 1970-1971 SURVEYS

County	Registered Vehicles	1969-1970 Vehicles With Studded Tires	1969-1970 Studded Tire Proportion	1970-1971 Vehicles With Studded Tires	1970-1971 Studded Tire Proportion
Alcona	3886	427.46	0.11	1088.08	0.28
Alger	3270	981.00	0.30	863.28	0.26
Allegan	27901	4812.92	0.17	7533.27	0.27
Alpena	13432	1007.40	0.08	3223.68	0.24
Antrim	5168	1292.00	0.25	1653.76	0.32
Arenac	4467	625.38	0.14	1206.09	0.27
Baraga	3231	969.30	0.30	1001.61	0.31
Barry	14301	3289.23	0.23	5219.87	0.37
Bay	50619	4120.39	0.08	8250.90	0.16
Benzie	3830	880.90	0.23	1455.40	0.38
Berrien	78346	9793.25	0.13	16766.04	0.21
Branch	15912	1352.52	0.09	1909.44	0.12
Calhoun	65290	6692.23	0.10	7998.03	0.12
Cass	19065	2478.45	0.13	4575.60	0.24
Charlevoix	6974	1255.32	0.18	2161.94	0.31
Cheboygan	6931	1594.13	0.23	2495.16	0.36
Chippewa	11691	1870.56	0.16	3331.94	0.29
Clare	6722	1344.40	0.20	1411.62	0.21
Clinton	16667	1583.37	0.10	3666.74	0.22
Crawford	2911	727.75	0.25	1018.85	0.35
Delta	14653	3003.87	0.21	4688.96	0.32
Dickinson	10815	2595.60	0.24	5299.35	0.49
Eaton	27415	2193.20	0.08	2823.75	0.10
Emmet	8261	2726.13	0.33	3304.40	0.40
Genesee	195742	17244.87	0.09	33520.82	0.17
Gladwin	5249	577.39	0.11	1417.23	0.27
Gogebic	8575	1457.75	0.17	3001.25	0.35
Grand Traverse	19371	4261.62	0.22	6683.00	0.35
Gratiot	16784	2601.52	0.16	2517.60	0.15
Hillsdale	16209	1458.81	0.09	2755.53	0.17
Houghton	12659	5316.78	0.42	5759.85	0.46
Huron	15225	2816.63	0.19	4872.00	0.32
Ingham	115471	14780.29	0.13	15357.64	0.13
Ionia	18462	3323.16	0.18	3877.02	0.21
Iosco	9432	660.24	0.07	1792.08	0.19
Iron	6118	734.16	0.12	1957.76	0.32
Isabella	13974	2165.97	0.16	2375.58	0.17
Jackson	62310	4050.15	0.07	12337.38	0.20
Kalamazoo	86705	15684.93	0.18	12919.04	0.15
Kalkaska	2411	530.42	0.22	650.97	0.27
Kent	185857	33212.65	0.18	39215.83	0.21
Keweenaw	837	292.95	0.35	309.69	0.37
Lake	2254	225.40	0.10	450.80	0.20
Lapeer	19530	1269.45	0.07	2538.90	0.13
Leelanau	4460	758.20	0.17	1694.80	0.38

TABLE 5 (Cont.)
COMPARISON OF 1969-1970 AND 1970-1971 SURVEYS

County	Registered Vehicles	1969-1970 Vehicles With Studded Tires	1969-1970 Studded Tire Proportion	1970-1971 Vehicles With Studded Tires	1970-1971 Studded Tire Proportion
Lenawee	36526	1826.30	0.05	5186.69	0.14
Livingston	22829	3349.01	0.15	4725.60	0.21
Luce	2374	688.46	0.29	640.98	0.27
Mackinac	3525	634.50	0.18	951.75	0.27
Macomb	282989	25469.01	0.09	21790.15	0.08
Manistee	8950	2148.00	0.24	3132.50	0.35
Marquette	24144	9730.03	0.40	10060.08	0.42
Mason	9652	1833.88	0.19	3185.16	0.33
Mecosta	9995	1599.20	0.16	2498.75	0.25
Menominee	10607	954.63	0.09	4348.87	0.41
Midland	29150	4372.50	0.15	6340.13	0.22
Missaukee	2795	698.75	0.25	978.25	0.35
Monroe	50784	3133.37	0.06	7262.11	0.14
Montcalm	17672	2120.64	0.12	5566.68	0.32
Montmorency	2418	241.80	0.10	386.88	0.16
Muskegon	68258	12511.69	0.18	17337.53	0.25
Newaygo	12423	3167.87	0.26	3229.98	0.26
Oakland	432637	47979.44	0.11	52349.08	0.12
Oceana	6638	1659.50	0.25	2389.68	0.36
Ogemaw	5116	869.72	0.17	1227.84	0.24
Ontonagon	4174	500.88	0.12	1460.90	0.35
Osceola	6262	1252.40	0.20	1565.50	0.25
Oscoda	2030	263.90	0.13	507.50	0.25
Otsego	4562	821.16	0.18	2007.28	0.44
Ottawa	55505	10623.66	0.19	13654.23	0.25
Presque Isle	5149	463.41	0.09	1390.23	0.27
Roscommon	5298	1006.62	0.19	1112.58	0.21
Saginaw	92725	8039.26	0.09	13074.22	0.14
Sanilac	14304	2002.56	0.14	1573.44	0.11
Schoolcraft	3619	1085.70	0.30	940.94	0.26
Shiawassee	26421	3521.92	0.13	3778.20	0.14
St. Clair	50958	4076.64	0.08	5299.63	0.10
St. Joseph	22152	2215.20	0.10	3034.82	0.14
Tuscola	19292	4147.78	0.22	4340.70	0.23
Van Buren	24204	3872.64	0.16	5978.39	0.25
Washtenaw	97229	10131.26	0.10	11424.41	0.12
Wayne	1178938	114239.10	0.10	117893.80	0.10
Wexford	9101	2184.24	0.24	3094.34	0.34

Weighted 1969-70 Statewide Tire Stud Proportion = 0.1195849

Weighted 1970-71 Statewide Tire Stud Proportion = 0.1524489

Increase in percent of cars having studded tires since 1969-70 = 3.2864 %.

TABLE 6
SUMMARY OF 1970-1971 STUDDED TIRE SURVEY DATA

County	Vehicle Registration	Number of Clusters in County	Number of Clusters Sampled	Vehicles per Cluster	Number of Vehicles With Studs	Proportion With Studs	Standard Deviation	Precision of Estimated Proportion With Studs (95% Confidence)
Alcona	3886	155.44	4	25	28	.28	.03	.03
Alger	3270	130.80	5	25	33	.264	.03	.03
Allegan	27901	558.02	8	50	108	.27	.02	.01
Alpena	13432	537.28	8	25	48	.24	.04	.03
Antrim	5168	206.72	4	25	32	.32	.03	.03
Arenac	4467	178.68	4	25	27	.27	.05	.05
Baraga	3231	129.24	4	25	31	.31	.02	.02
Barry	14301	572.04	8	25	73	.36	.03	.02
Bay	50619	1012.38	14	50	114	.16	.02	.01
Benzie	3830	153.20	4	25	38	.38	.06	.06
Berrien	78346	783.46	10	100	214	.214	.02	.01
Branch	15912	636.48	8	25	24	.12	.02	.01
Calhoun	65290	652.90	8	100	98	.12	.01	.01
Cass	19065	762.60	4	25	24	.24	.05	.05
Charlevoix	6974	278.96	4	25	31	.31	.02	.02
Cheboygan	6931	277.24	4	25	36	.36	.03	.03
Chippewa	11691	467.64	8	25	57	.28	.04	.03
Clare	6722	268.88	4	25	21	.21	.02	.02
Clinton	16667	666.68	8	25	44	.22	.03	.02
Crawford	2911	116.44	4	25	35	.35	.06	.06
Delta	14653	586.12	8	25	63	.315	.05	.03
Dickinson	10815	432.60	4	25	49	.49	.03	.03
Eaton	27415	1096.60	12	25	31	.10	.01	.01
Emmet	8261	330.44	4	25	40	.40	.03	.03
Genesee	195742	1957.42	8	100	137	.17	.02	.01
Gladwin	5249	209.96	4	25	27	.27	.03	.03
Gogebic	8575	343.00	4	25	35	.35	.04	.04
Grand Traverse	19371	774.84	8	25	69	.35	.03	.02
Gratiot	16784	671.36	8	25	30	.15	.03	.02
Hillsdale	16209	648.36	8	25	34	.17	.02	.01
Houghton	12659	506.36	8	25	91	.46	.07	.05
Huron	15225	609.00	8	25	64	.37	.05	.03
Ingham	115471	1154.71	12	100	160	.13	.01	.01
Ionia	18462	738.48	8	25	42	.21	.03	.02
Iosco	9432	377.28	4	25	19	.19	.03	.03
Iron	6118	244.72	4	25	32	.32	.02	.02
Isabella	13974	558.96	8	25	34	.17	.03	.02
Jackson	62310	1246.20	12	50	119	.20	.03	.02
Kalamazoo	86705	867.05	11	100	164	.15	.03	.02
Kalkaska	2411	96.44	4	25	27	.27	.03	.03
Kent	185857	1858.57	15	100	316	.21	.01	.01
Keweenaw	837	33.48	4	25	37	.37	.02	.02

TABLE 6 (Cont.)
SUMMARY OF 1970-1971 STUDDED TIRE SURVEY DATA

County	Vehicle Registration	Number of Clusters in County	Number of Clusters Sampled	Vehicles per Cluster	Number of Vehicles With Studs	Proportion With Studs	Standard Deviation	Precision of Estimated Proportion With Studs (95% Confidence)
Lake	2254	90.16	4	25	20	.20	.04	.04
Lapeer	19530	781.20	8	25	26	.13	.03	.02
Leelanau	4460	178.40	4	25	38	.38	.08	.08
Lenawee	36526	730.52	10	50	71	.14	.02	.01
Livingston	22829	913.16	12	25	62	.21	.03	.02
Luce	2374	94.96	4	25	27	.27	.03	.03
Mackinac	3525	141.00	4	25	27	.27	.06	.06
Macomb	282989	2829.89	10	100	77	.08	.01	.01
Manistee	8950	358.00	4	25	35	.35	.05	.05
Marquette	24144	965.76	12	25	125	.42	.04	.02
Mason	9652	386.08	4	25	33	.33	.01	.01
Mecosta	9995	399.80	4	25	25	.25	.06	.06
Menominee	10607	424.28	4	25	41	.41	.07	.07
Midland	29150	583.00	8	50	87	.22	.02	.01
Missaukee	2795	111.80	4	25	35	.35	.04	.04
Monroe	50784	1015.68	12	50	86	.14	.02	.01
Montcalm	17672	706.88	8	25	63	.32	.03	.02
Montmorency	2418	96.72	4	25	16	.16	.04	.04
Muskegon	68258	1365.16	18	50	229	.25	.02	.01
Newaygo	12423	496.92	8	25	52	.26	.02	.01
Oakland	432637	4326.37	12	100	145	.12	.02	.01
Oceana	6638	265.52	4	25	36	.36	.09	.09
Ogemaw	5116	204.64	4	25	24	.24	.04	.04
Ontonagon	4174	166.96	4	25	35	.35	.04	.04
Osceola	6262	250.48	4	25	25	.25	.06	.06
Oscoda	2030	81.20	4	25	25	.25	.05	.05
Otsego	4562	182.48	4	25	44	.44	.04	.04
Ottawa	55505	1110.10	14	50	172	.25	.02	.01
Presque Isle	5149	205.96	4	25	27	.27	.05	.05
Roscommon	5298	211.92	4	25	21	.21	.01	.01
Saginaw	92725	927.25	9	100	127	.24	.02	.01
Sanilac	14304	572.16	8	25	22	.11	.02	.01
Schoolcraft	3619	144.76	4	25	26	.26	.04	.04
Shiawassee	26421	1056.84	12	25	43	.14	.02	.01
St. Clair	50958	1019.16	14	50	73	.10	.01	.01
St. Joseph	22152	886.08	12	25	41	.14	.02	.01
Tuscola	19292	771.68	8	25	45	.23	.04	.03
Van Buren	24204	968.16	12	25	74	.25	.03	.02
Washtenaw	97229	972.29	12	100	141	.12	.02	.01
Wayne	1178938	11789.38	15	100	150	.10	.01	.01
Wexford	9101	364.04	4	25	34	.34	.02	.02

TABLE 7
RESULTS, BY COUNTIES, OF 1971 TIRE SURVEY

County	Vehicle Tire Condition, percent				
	One Smooth	Two Smooth	Three Smooth	All Smooth	None Smooth
Alcona	1.00	10.00	0.00	2.00	87.00
Alger	4.80	8.80	1.60	2.40	82.40
Allegan	5.50	13.00	0.50	0.75	80.25
Alpena	6.00	7.00	0.50	0.50	86.00
Antrim	4.00	10.00	0.00	4.00	82.00
Arenac	6.00	17.00	1.00	2.00	74.00
Baraga	5.00	4.00	0.00	0.00	91.00
Barry	5.50	11.00	1.50	4.00	78.00
Bay	4.86	9.00	1.00	2.57	82.57
Benzie	3.00	6.00	2.00	1.00	88.00
Berrien	2.80	13.20	0.90	4.20	78.90
Branch	5.50	7.00	1.50	4.50	81.50
Calhoun	6.25	7.13	1.50	4.50	79.37
Cass	2.00	11.00	0.00	2.00	85.00
Charlevoix	4.00	11.00	1.00	5.00	79.00
Cheboygan	0.00	13.00	0.00	0.00	87.00
Chippewa	4.00	4.00	0.00	0.00	92.00
Clare	1.00	11.00	1.00	5.00	82.00
Clinton	3.50	2.00	0.00	1.50	93.00
Crawford	3.00	16.00	0.00	5.00	76.00
Delta	5.50	7.00	0.50	0.00	87.00
Dickinson	5.00	3.00	2.00	0.00	90.00
Eaton	3.67	2.67	0.33	0.33	93.00
Emmet	3.00	11.00	0.00	1.00	85.00
Genesee	5.00	8.88	0.87	2.25	83.00
Gladwin	9.00	12.00	0.00	2.00	77.00
Gogebic	0.00	3.00	0.00	0.00	97.00
Grand Traverse	2.00	3.00	0.50	0.50	94.00
Gratiot	3.50	10.50	1.50	3.50	81.00
Hillsdale	3.00	4.00	0.50	0.00	92.50
Houghton	5.50	3.00	0.00	0.00	91.50
Huron	7.50	16.50	0.50	3.50	72.00
Ingham	3.92	2.33	0.08	0.08	93.59
Ionia	5.50	14.00	1.50	3.00	76.00
Iosco	4.00	13.00	0.00	1.00	82.00
Iron	4.00	2.00	0.00	0.00	94.00
Isabella	3.00	17.50	1.50	1.50	76.50
Jackson	3.67	3.83	0.33	0.83	91.84
Kalamazoo	4.46	12.08	0.63	3.27	79.56
Kalkaska	2.00	13.00	2.00	5.00	78.00
Kent	6.33	10.47	0.93	2.00	80.27
Keweenaw	3.00	2.00	0.00	0.00	95.00

TABLE 7 (Cont.)
RESULTS, BY COUNTIES, OF 1971 TIRE SURVEY

County	Vehicle Tire Condition, percent				
	One Smooth	Two Smooth	Three Smooth	All Smooth	None Smooth
Lake	2.00	3.00	0.00	0.00	95.00
Lapeer	6.00	7.00	1.00	5.00	81.00
Leelanau	6.00	4.00	1.00	0.00	89.00
Lenawee	3.20	2.20	0.00	0.40	94.20
Livingston	5.00	4.33	0.67	0.00	90.00
Luce	2.00	1.00	1.00	0.00	96.00
Mackinaw	3.00	4.00	0.00	0.00	93.00
Macomb	2.90	8.40	0.50	2.00	86.20
Manistee	4.00	5.00	0.00	1.00	90.00
Marquette	3.33	4.00	0.00	0.00	92.67
Mason	4.00	7.00	0.00	1.00	88.00
Mecosta	4.00	5.00	0.00	0.00	91.00
Menominee	4.00	7.00	1.00	1.00	87.00
Midland	3.00	11.25	0.75	0.75	84.25
Missaukee	3.00	13.00	2.00	2.00	80.00
Monroe	5.00	4.50	0.33	0.17	90.00
Montcalm	0.50	4.00	0.00	0.00	95.50
Montmorency	1.00	11.00	0.00	0.00	88.00
Muskegon	1.56	1.33	0.11	0.00	97.00
Newago	5.50	2.00	0.50	0.50	91.50
Oakland	3.83	8.40	1.44	1.83	84.50
Oceana	4.00	1.00	0.00	0.00	95.00
Ogemaw	3.00	12.00	2.00	1.00	82.00
Ontonagon	4.00	4.00	0.00	0.00	92.00
Osceola	4.00	4.00	0.00	0.00	92.00
Oscoda	2.00	9.00	1.00	1.00	87.00
Otsego	2.00	9.00	0.00	3.00	86.00
Ottawa	5.72	12.14	1.57	1.57	79.00
Presque Isle	3.00	9.00	2.00	2.00	84.00
Roscommon	3.00	5.00	0.00	5.00	87.00
Saginaw	4.33	11.67	2.00	2.00	80.00
Sanilac	1.00	13.50	1.50	1.00	83.00
Schoolcraft	5.00	11.00	0.00	1.00	83.00
Shiawassee	8.33	6.00	0.00	1.33	84.34
St. Clair	5.57	9.43	1.43	3.85	79.71
St. Joseph	3.67	10.33	1.00	2.67	82.33
Tuscola	4.00	13.00	0.50	5.00	77.50
Van Buren	5.67	8.33	1.67	2.67	81.66
Washtenaw	4.42	3.84	0.33	0.08	91.33
Wayne	5.06	8.60	0.87	1.87	83.60
Wexford	2.00	3.00	0.00	1.00	94.00

TABLE 8
1971 MICHIGAN TREAD WEAR AND SNOW TIRE SURVEY

Tire Classification	Passenger Cars	Pickup and Panel Trucks	4-Wheel Drive Vehicles
one half-smooth	0.005	0.001	.0
two half-smooth	0.003	0	0
one smooth	0.040	0.024	0.007
two smooth	0.081	0.071	0.004
three smooth	0.008	0.005	0
four smooth	0.018	0.024	0.005
with smooth tires	0.155	0.125	0.029
without smooth tires	0.845	0.875	0.971
with snow tires	0.438	0.651	0.870
without snow tires	0.562	0.349	0.130

APPENDIX A

DEVELOPMENT OF SAMPLING PLAN FOR TIRE STUD SURVEY

It is known that tire stud use varies greatly between areas of the State, probably as a function of average snow fall, character of terrain (hilly or flat), and economic condition. Therefore, one Statewide estimator of the proportion of vehicles with tire studs would not be as accurate for investigating wear on a given highway as would a local estimator. The Statewide estimator could be heavily weighted by large population centers and might not be a good indicator for a county such as Houghton which has high snow-fall, hilly terrain, but a relatively small number of vehicles. Therefore, it appears that stratified sampling would be appropriate, with each strata contributing to a Statewide estimate of parameters but also serving as a local estimator. Since vehicle registration data are available for each of Michigan's 83 counties the State will be stratified into counties and registration data will be used for determining sample size and allocation.

Moreover, each item in the sample will be classified simply as to whether it does or does not have tire studs, so the situation is a natural for sampling for proportions. The 1969-1970 survey indicated that variations in proportions of vehicles with studded tires was great enough between counties to warrant a Neyman allocation, rather than proportional, since variance is a function of proportion (p). Therefore, the results of the 1969-1970 survey will be used in allocating the sample.

To summarize: the sample space will consist of all automobiles registered in Michigan; for estimates of county parameters, the sample space will be all automobiles in the county, elementary units will be automobiles, the random variable x_{hj} takes on values of 1 if an automobile j in county h has studded tires or 0 if not, and the vehicle registration list, at least initially, is the sampling frame. Statistical parameters will be estimated.

Statewide Estimation

For a first estimate of total sample size, the finite population correction (fpc) will be ignored and the expression will be:

$$n_0 = \frac{1}{N^2} \frac{\left(\sum_{h=1}^{83} N_h \sqrt{p_h q_h} \right)^2}{V}$$

where:

- n_o = number of automobiles in total sample
- N_h = number of automobiles registered in county h
- N = number of automobiles registered in state
- p_h = estimated fraction of automobiles in county h with studded tires
- q_h = estimated fraction of automobiles in county h without studded tires ($1 - p_h$)
- V = desired variance

let the desired confidence level = 95 percent

the desired precision = 0.02 (2%)

then:

$$V = \left(\frac{0.02}{1.96} \right)^2 \cong (0.01)^2 = 0.0001$$

After n_o is computed, a corrected value of total sample size (n) will be computed:

$$n = \frac{n_o}{1 + \frac{1}{NV} \sum_{h=1}^N W_h p_h q_h} = \frac{n_o}{1 + \frac{1}{N^2 V} \sum N_h p_h q_h}$$

The preceding allocations are not exact since two stage cluster sampling for proportions is to be used within each stratum. However, simple random sampling (SRS) will be assumed for this first estimate which is based on data from last year. For next year's survey, better estimates of parameters should be available to aid in making a more precise allocation.

The proportion of automobiles in the sample space (State) will be estimated by:

$$\hat{p}_{st} = \frac{1}{N} \sum_{h=1}^{83} N_h p_h$$

where:

- N_h = number of automobiles in stratum h
- p_h = proportion of automobiles with studded tires in stratum h
- N = number of automobiles in sample space

For reasons discussed later, two stage cluster sampling will be used within each stratum. The variance of an estimated population total (X) is estimated by:

$$\hat{V}(\hat{X}) = \sum^L M_h^2 \frac{M_h - m_h}{M_h} \frac{s_h^2}{m_h} + \sum^L \frac{M_h}{m_h} \sum^{m_h} N_{hi}^2 \frac{N_{hi} - n_{hi}}{N_{hi}} \frac{s_{hi}^2}{n_{hi}}$$

and since $P_{st} = \frac{X}{N}$, the preceding expression can be multiplied by $\frac{1}{N^2}$ to determine $V(P_{st})$.

where:

- M_h = number of clusters or primary sampling units (psu) within stratum h from which m_h sample clusters or secondary sampling units (ssu) are selected.
- s_h^2 = represents variation between psu within county h
- s_{hi}^2 = represents variation within the i th psu of stratum h
- N_{hi} = number of ssu in psu i of county h
- n_{hi} = number of ssu taken from psu i of county h
- L = number of counties = 83

Within County Estimations

Using the preceding steps an estimate can be obtained, valid Statewide, of the proportion of automobiles using studded tires. Another equally important goal is to estimate, with desired precision and accuracy, the proportion of automobiles with studded tires within each county.

For survey efficiency, clusters will be selected by randomly selecting primary sampling units (psu) which will be towns or cities within each county. Surveyors will be instructed to travel to each designated town or city and inspect the first cluster consisting of a given number of automobiles that they encounter, which are parked on a public street or parking lot. This cluster, inspected by surveyors, will be the ssu. All ssu within any given county will be equal and will consist of n automobiles.

Obviously all automobiles in every county are not located exclusively in towns or cities. Therefore, samples will be biased in favor of automobiles located in cities or towns during workdays when surveys are made.

For a preliminary estimate of the number of automobiles to be sampled in each county, the following expression will be used:

$$n_h = \frac{N_h Z^2 P_h q_h}{N_h d^2 + Z^2 P_h q_h}$$

- n_h = sample size in number of automobiles for county h
- N_h = number of automobiles in county h
- p_h = proportion of automobiles with studded tires in county h
- q_h = (1 - p_h)
- d = desired precision of estimate (= 0.02 in this case)
- Z = number of standard deviates to give desired confidence level.
In this case, desired confidence level is 95 so $Z = 2$.

Although the above formula is not exact for our survey, since it applies to SRS without replacement, it will give us an approximate sample size.

In order to obtain an unbiased estimate of P_h for each county, towns or cities will be selected randomly with probability proportional to size, with replacement (pps wr). Data listing the number of automobiles located in each city or town cannot be obtained without great difficulty so cities or towns will be weighted, for probability of selection, by population count. It appears reasonable to assume that, within each county, population is directly related to number of automobiles.

Then an unbiased estimator of P_h is:

$$\hat{P}_{h\text{pps wr}} = \frac{1}{m} \sum_{i=1}^m p_i$$

and the variance is estimated by:

$$\hat{V}(\hat{P}_{h\text{pps wr}}) = \frac{1}{m} \frac{1}{m-1} \sum_{i=1}^m (p_i - \hat{P}_{h\text{pps wr}})^2$$

where:

- m = number of psu
- p_i = proportion of vehicles having studded tires in ssu from cluster (psu) i

$$p_i = \frac{1}{\bar{n}} \sum_{j=1}^{\bar{n}} x_{ij}$$

x_{ij} = car j in cluster (psu) i

\bar{n} = number of cars in ssu.

Details

Surveyors will work in pairs, one recorder and one inspector. A broom or brush will be carried by each pair to clean snow or mud-covered tires where necessary. A letter, describing the survey and written with Department letterhead, will be carried by each team in case they are confronted by police, parking lot guards, etc., while inspecting automobiles. Where parking lots are conspicuously guarded, the letter will be presented and permission requested before beginning the survey.

Survey forms, similar to the one attached, will be used for recording data with one form being used for each cluster.

Remarks

Table 9 lists the total sample size and Neyman allocation of the sample for each county. This was determined on the basis of sampling sufficient to estimate parameters for the State as a whole. For many counties, the sample size is unrealistically small, less than one vehicle for some counties. If this sample allocation were to be used in the survey, each county should be examined and the sample size increased in almost every case, especially since costs for sampling elementary units are so small, once the surveyors have traveled to the area. However, as seen in the following, a much larger sample is required to estimate parameters for each county.

Table 10 lists sample sizes appropriate for surveys to estimate individual county parameters. In the case of the Statewide estimate, a total sample size was first determined (1005 automobiles in this case) and then allocated to each county. For county estimates, sample sizes necessary to obtain desired precision were estimated for each county and these values were summed to give the total for the State (92,256 in this case). Thus, for equal precision in the survey, it would take a sample about 92 times as large to estimate parameters valid for each county as it would if only Statewide parameters were estimated.

In the case of the individual county survey (Table 10), samples for each county are too large to be practical in many cases. For example, Keweenaw County (No. 42) only has 837 registered automobiles. Yet a sample size of 612 is necessary to give a 95 percent confidence of precision within 2 percent. For the actual survey, a modified version of the Table 10 allocation will be used. Counties will be grouped by similar numbers of automobile registrations and separate precisions established for each group. To illustrate why a precision in percent would not have to be identical for each

county, an error of 10% in the estimated proportion of studded tire vehicles in Wayne County would be much more serious than in Keweenaw in estimating repetition of studded tires traveling over a pavement. Details and results of the sample survey actually used are listed in Table 6.

REFERENCES

Cochran, W. G., Sampling Techniques, Wiley, N. Y., 1963.

Raj, D., Sampling Theory, McGraw-Hill, N. Y., 1968.

Yamane, T., Elementary Sampling Theory, Prentice-Hall, N. Y., 1967.

TABLE 9
 SAMPLE ALLOCATION FOR DETERMINATION OF PROPORTION OF VEHICLES
 IN STATE USING TIRE STUDS

County	Registered Vehicles	Proportion With Studs	Required Sample	County	Registered Vehicles	Proportion With Studs	Required Sample
Alcona	3886	0.11	0.99	Lake	2254	0.10	0.55
Alger	3270	0.30	1.22	Lapeer	19530	0.07	3.91
Allegan	27901	0.17	8.57	Leelanau	4460	0.17	1.36
Alpena	13432	0.08	2.88	Lenawee	36526	0.05	6.47
Antrim	5168	0.25	1.82	Livingston	22829	0.15	6.56
Arenac	4467	0.14	1.26	Luce	2374	0.29	0.88
Baraga	3231	0.30	1.20	Mackinac	3525	0.18	1.10
Barry	14301	0.23	4.89	Macomb	282989	0.09	65.82
Bay	50619	0.08	11.25	Manistee	8950	0.24	3.11
Benzie	3830	0.23	1.31	Marquette	24144	0.40	9.63
Berrien	78346	0.13	21.06	Mason	9652	0.19	3.08
Branch	15912	0.09	3.61	Mecosta	9995	0.16	2.98
Calhoun	65290	0.10	16.09	Menominee	10607	0.09	2.47
Cass	19065	0.13	5.21	Midland	29150	0.15	8.46
Charlevoix	6974	0.18	2.18	Missaukee	2795	0.25	0.98
Cheboygan	6931	0.23	2.37	Monroe	50784	0.06	9.93
Chippewa	11691	0.16	3.48	Montcalm	17672	0.12	4.67
Clare	6722	0.20	2.19	Montmorency	2418	0.10	0.59
Clinton	16667	0.10	3.97	Muskegon	68258	0.18	21.46
Crawford	2911	0.25	1.02	Newaygo	12423	0.26	4.40
Delta	14653	0.21	4.81	Oakland	432637	0.11	110.40
Dickinson	10815	0.24	3.75	Oceana	6638	0.25	2.34
Eaton	27415	0.08	6.04	Ogemaw	5116	0.17	1.56
Emmet	8261	0.33	3.16	Ontonagon	4174	0.12	1.10
Genesee	195742	0.09	45.09	Osceola	6262	0.20	2.04
Gladwin	5249	0.11	1.33	Oscoda	2030	0.13	0.55
Gogebic	8575	0.17	2.62	Otsego	4562	0.18	1.42
Grand Traverse	19371	0.22	6.52	Ottawa	55505	0.19	17.75
Gratiot	16784	0.16	4.94	Presque Isle	5149	0.09	1.20
Hillsdale	16209	0.09	3.77	Roscommon	5298	0.19	1.69
Houghton	12659	0.42	5.08	Saginaw	92725	0.09	21.20
Huron	15225	0.19	4.80	Sanilac	14304	0.14	4.03
Ingham	115471	0.13	31.35	Schoolcraft	3619	0.30	1.35
Ionia	18462	0.18	5.76	Shiawassee	26421	0.13	7.30
Iosco	9432	0.07	1.96	St. Clair	50958	0.08	11.23
Iron	6118	0.12	1.62	St. Joseph	22152	0.10	5.40
Isabella	13974	0.16	4.11	Tuscola	19292	0.22	6.44
Jackson	62310	0.07	12.48	Van Buren	24204	0.16	7.21
Kalamazoo	86705	0.18	27.12	Washtenaw	97229	0.10	24.14
Kalkaska	2411	0.22	0.81	Wayne	1178938	0.10	283.43
Kent	185857	0.18	57.86	Wexford	9101	0.24	3.16
Keweenaw	837	0.35	0.32				
				TOTAL			1005.22

TABLE 10
 SAMPLE ALLOCATION FOR DETERMINATION OF PROPORTION OF
 VEHICLES USING STUDDED TIRES IN EACH COUNTY

County	Registered Vehicles	Proportion With Studs	Required Sample	County	Registered Vehicles	Proportion With Studs	Required Sample
Alcona	3886	0.11	781.99	Lake	2254	0.10	643.18
Alger	3270	0.30	1278.77	Lapeer	19530	0.07	589.41
Allegan	27901	0.17	1357.96	Leelanau	4460	0.17	1071.89
Alpena	13432	0.08	659.68	Lenawee	36526	0.05	468.90
Antrim	5168	0.25	1375.83	Livingston	22829	0.15	1186.72
Arenac	4467	0.14	948.38	Luce	2374	0.29	1102.65
Baraga	3231	0.30	1272.76	Mackinac	3525	0.18	1040.37
Barry	14301	0.23	1575.85	Macomb	282989	0.09	816.64
Bay	50619	0.08	736.86	Manistee	8950	0.24	1515.20
Benzie	3830	0.23	1211.02	Marquette	24144	0.40	2188.37
Berrien	78346	0.13	1078.69	Mason	9652	0.19	1327.36
Branch	15912	0.09	741.51	Mecosta	9995	0.16	1184.70
Calhoun	65290	0.10	907.16	Menominee	10607	0.09	760.30
Cass	19065	0.13	1067.66	Midland	29150	0.15	1221.57
Charlevoix	6974	0.18	1218.18	Missaukee	2795	0.25	1122.19
Cheboygan	6931	0.23	1410.57	Monroe	50784	0.06	572.41
Chippewa	11691	0.16	1205.42	Montcalm	17672	0.12	996.46
Clare	6722	0.20	1292.38	Montmorency	2418	0.10	655.88
Clinton	16667	0.10	817.58	Muskegon	68258	0.18	1464.88
Crawford	2911	0.25	1140.44	Newaygo	12423	0.26	1647.77
Delta	14653	0.21	1466.63	Oakland	432637	0.11	983.77
Dickinson	10815	0.24	1560.77	Oceana	6638	0.25	1462.03
Eaton	27415	0.08	716.76	Ogemaw	5116	0.17	1105.97
Emmet	8261	0.33	1744.18	Ontonagon	4174	0.12	842.78
Genesee	195742	0.09	800.10	Osceola	6262	0.20	1274.38
Gladwin	5249	0.11	825.11	Oscoda	2030	0.13	726.33
Gogebic	8575	0.17	1211.63	Otsego	4562	0.18	1115.19
Grand Traverse	19371	0.22	1576.36	Ottawa	55505	0.19	1505.68
Gratiot	16784	0.16	1214.94	Presque Isle	5149	0.09	706.61
Hillsdale	16209	0.09	779.61	Roscommon	5298	0.19	1192.57
Houghton	12659	0.42	2042.88	Saginaw	92725	0.09	785.13
Huron	15225	0.19	1371.89	Sanilac	14304	0.14	1110.53
Ingham	115471	0.13	1105.47	Schoolcraft	3619	0.30	1328.89
Ionia	18462	0.18	1366.73	Shiawassee	26421	0.13	1106.91
Iosco	9432	0.07	608.97	St. Clair	50958	0.08	725.52
Iron	6118	0.12	900.56	St. Joseph	22152	0.10	864.86
Isabella	13974	0.16	1197.51	Tuscola	19292	0.22	1551.98
Jackson	62310	0.07	601.88	Van Buren	24204	0.16	1273.30
Kalamazoo	86705	0.18	1456.86	Washtenaw	97229	0.10	924.55
Kalkaska	2411	0.22	1002.49	Wayne	1178938	0.10	874.45
Kent	185857	0.18	1456.16	Wexford	9101	0.24	1519.47
Keweenaw	837	0.35	611.88				
				TOTAL			92255.79