

**Statewide Sampling Protocol and Management Strategy for
Assessing Field Maintenance Activities**

**Statistical Analysis of the
Summer 2002 Survey Data**

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1 Introduction

This project addresses a structured long-term data collection plan of maintenance activities statewide in Montana. One goal of the project is the formulation of a statewide sampling protocol for maintenance activities requiring field assessment as defined in the AMMO (Accountability for Montana's Maintenance Operations) Field Data Collection Manual.

A surveying protocol based on statistically-sound sampling principles is needed for successful implementation of the AMMO process.

Statistically-based survey sampling methods were developed based on available information of centerline miles to define natural stratification criteria of roadway miles statewide. The statistical methodology used to generate the stratified sampling plan of roadway sites was summarized in the report *A Report on the Sampling Methodology used for the Summer 2002 Data Collection*.

This report summarizes the assessment of the current state of 20 maintenance activities based on analysis of the survey data collected during the summer of 2002.

2 Actual vs. Potential Survey Miles

The stratified sampling plan required each of the 11 maintenance divisions to survey approximately ten centerline miles of roadway for a potential of 110 total centerline miles of roadway statewide. Because it could not be determined prior to surveying whether or not a roadway segment in the sample would possess certain characteristics associated with each maintenance activity, the actual miles of roadway in the survey that possess that characteristic will be less than the 110 potential miles.

- For example, protective barriers will only be found on a subset of the 110 potential roadway miles. In particular, no protective barriers were found for any of the urban (URB) highway type roadway segments and for a total of only 9.9 miles in the entire survey.

Analogously, it could not be determined prior to surveying whether or not certain structures would be present when a roadway segment was surveyed.

- For example, crash barriers will only be found on a subset of the 110 potential roadway miles. In particular, no crash barriers were found for any of the Missoula, Glendive, and Miles City maintenance division roadway segments. A total of 57 crash barriers were observed in the entire survey.

A summary of the actual mileage and number of structures observed in the survey are given in Tables 1A and 1B and Table 2, respectively.

3 Maintenance Activity Estimates

For each of the maintenance activities, estimates were calculated along with standard error estimates and approximate 95% confidence intervals. Statistical formulas and methodology behind these estimates can be found in the Appendix.

Statewide Estimates

Statewide estimates associated with maintenance activities are summarized in Table 3. Here is a description of the values contained in the table.

1. A value in the “Estimate” column represents the data-based estimate expressed as a percentage or in terms of pieces per mile (depending on the type of maintenance activity).
2. Because we only have a sample (and not a census) of roadway segments, our estimates are subject to sampling variability. That is, if a different sample of roadway segments were sampled we would not expect to get the same value as the original estimate. A measure of the sampling variability associated with our estimate is the standard error. The values in the “s.e.” column represent the standard errors associated with the estimates. A standard error is also expressed as a percentage or in terms of pieces per mile. A smaller standard error indicates a more precise estimate while a larger standard error indicates a less precise estimate. These values will be important to use when future sampling surveys are planned.
3. Often it is desirable not to have just an estimate and its standard error, but also to have a confidence interval estimate. The values in the two “95% CI” columns represent the lower and upper endpoints of the 95% confidence interval for the true percentage or true pieces per mile associated with that maintenance activity. In other words, we are saying that we are 95% confident that the true percentage or true pieces per mile is between these two values. This interval will always contain the value in the estimate column.

For example:

- The estimated percentage of drainage structures that are acceptable statewide is 69.1% and the estimated pieces of litter per mile statewide is 16.6 pieces.

- The standard error associated with 69.1% estimate of drainage structures that are acceptable statewide is 2.6% and the standard error associated with the 16.6 pieces of litter per mile estimate is 1.6 pieces per mile.
- The 95% confidence interval for the true percentage of drainage structures that are acceptable statewide is between 64.2% and 74.6%. The 95% confidence interval for the actual pieces of litter per mile statewide is between 14.3 and 20.4 pieces of litter per mile.

Note that two estimates are given for right, center, and left striping. First, there are the estimates in rows 18a, 19a, and 20a in Table 3 which do not take into account striping reflectivity. Specifically, a length of pavement striping is considered unacceptable if greater than 25% is missing or worn away. The second set of estimates in rows 18b, 19b, and 20b also take into account striping reflectivity. That is, a length of pavement striping is considered unacceptable if greater than 25% is missing or worn away or a reflectivity reading is below 120 millicandelas per square meter per lux.

The values in Table 3 should provide insight to the Maintenance Division of the Montana Department of Transportation regarding whether or not the estimates suggest any changes need to be adopted statewide.

To provide even greater insight into the statewide estimates in Table 3, estimates will now be provided for each maintenance activity for (i) each of the five highway types and for (ii) each of the 11 maintenance divisions.

Estimates by Highway Type

Estimates of roadside and roadway maintenance activities for each highway type are summarized in Table 4, and estimates of traffic maintenance activities for each highway type are summarized in Table 5. The standard error of an estimate is in parentheses below the estimate.

For each maintenance activity, the five estimates provide information regarding differences in estimated percentages or differences in terms of pieces per mile across the five highway types. For example:

- In Table 4, the estimated percentages of acceptable drainage structures are 71.9%, 53.4%, 70.9%, 67.9%, and 89.9%, respectively, for NHS, OFF, PRI, SEC, and URB highway types. These values, when compared to the 69.1% statewide estimate in Table 3, indicate that there is a relatively lower percentage of acceptable OFF drainage structures while there is a relatively higher percentage of acceptable URB drainage structures.

- In Table 4, the estimated pieces of litter per mile are 22.1, 5.6, 10.2, 15.4, and 152.8, respectively, for NHS, OFF, PRI, SEC, and URB highway types. These values, when compared to the statewide estimate of 16.6 pieces per mile in Table 3, indicate that there is a relatively fewer pieces of litter per mile for OFF routes while there are many more pieces of litter per mile for URB routes.

If there was widespread absence of the structure or property associated with a maintenance activity for certain highway types, then it may not be possible to provide an estimate, a standard error, or a confidence interval for that division. 95% confidence interval estimates by highway type can be found in Table 8 and Table 9.

Estimates by Maintenance Division

Estimates of roadside and roadway maintenance activities for each maintenance division are summarized in Table 6, and estimates of traffic maintenance activities for each maintenance division are summarized in Table 7. The standard error of an estimate is in parentheses below the estimate.

For each maintenance activity, the eleven estimates provide information regarding differences in estimated percentages or differences in terms of pieces per mile across the eleven maintenance division. For example:

- In Table 6, the estimated percentages of acceptable drainage structures are 57.0%, 89.0%, 63.8%, 53.3%, 59.7%, 60.1%, 60.9%, 75.7%, 83.1%, 91.0% and 89.9%, respectively, for maintenance divisions 11, 12, 21, 22, 31, 32, 41, 42, 43, 51, and 53. These values, when compared the 69.1% statewide estimate in Table 3, indicate that there is a relatively lower percentage of acceptable drainage structures for the Bozeman (22) and Missoula (11) divisions while there is a relatively higher percentage of acceptable drainage structures for the Billings (51) division.
- In Table 6, the estimated pieces of litter per mile are 10.5, 1.6, 16.9, 7.4, 8.8, 15.1, 37.2, 36.2, 12.4, 29.5, and 11.8 respectively, for maintenance divisions 11, 12, 21, 22, 31, 32, 41, 42, 43, 51, and 53. These values, when compared to the statewide estimate of 16.6 pieces per mile in Table 3, indicate that there is a relatively fewer pieces of litter per mile for the Kalispell (12) division.

If there was widespread absence of the structure or property associated with a maintenance activity for certain maintenance divisions, then it may not be possible to provide an estimate, a standard error, or a confidence interval for that division. 95% confidence interval estimates by maintenance division can be found in Table 10 and Table 11.

TABLE 1A:
ACTUAL MILEAGE IN SURVEY FOR
TRAFFIC AND ROADWAY MAINTENANCE ACTIVITIES

Statewide	Right striping	Center Striping	Left Striping	Protective barriers	Debris	Swept Roadway
Total	107.5	90.2	107.1	9.9	109.4	108.8

Highway type	Right striping	Center Striping	Left Striping	Protective barriers	Debris	Swept Roadway
NHS	45.7	31.4	45.3	7.5	45.2	45.2
OFF	8.1	6.9	8.2	0.3	9.6	9.0
PRI	27.0	27.3	26.9	1.7	27.4	27.4
SEC	25.2	21.9	25.3	0.4	25.6	25.6
URB	1.5	2.7	1.4	0.0	1.6	1.6

Maintenance division	Right striping	Center Striping	Left Striping	Protective barriers	Debris	Swept Roadway
11	9.6	7.7	9.7	2.7	10.0	10.0
12	9.8	14.5	9.8	1.3	9.8	9.8
21	9.7	5.6	9.4	1.0	9.6	9.4
22	10.0	10.8	9.9	1.0	10.0	10.0
31	9.7	7.7	9.6	1.0	10.2	10.2
32	10.0	8.0	10.2	0.2	10.2	10.2
41	9.8	7.0	9.8	0.7	10.0	9.8
42	10.0	7.4	9.8	0.1	10.0	10.0
43	9.1	6.0	9.1	0.6	9.8	9.6
51	10.0	7.0	9.9	0.8	9.8	9.8
53	10.0	8.5	10.0	0.6	10.0	10.0

11 = Missoula

12 = Kalispell

21 = Butte

22 = Bozeman

31 = Great Falls

32 = Havre

41 = Glendive

42 = Wolf Point

43 = Miles City

51 = Billings

53 = Lewistown

TABLE 1B:
ACTUAL MILEAGE IN SURVEY FOR
ROADSIDE MAINTENANCE ACTIVITIES

Statewide	Fencing	Mowing	Nuisance vegetation	Paths & sidewalks	Slopes & ditches	Litter
Total	19.1	189.4	194.9	6.1	191.9	205.9

Highway type	Fencing	Mowing	Nuisance vegetation	Paths & sidewalks	Slopes & ditches	Litter
NHS	19.1	78.1	80.9	1.5	79.7	83.7
OFF	.	18.3	18.8	0.4	18.6	19.6
PRI	.	46.4	47.3	2.0	47.1	52.0
SEC	.	44.4	45.6	0.4	44.8	47.4
URB	.	2.1	2.3	1.8	1.7	3.2

Maintenance Division	Fencing	Mowing	Nuisance vegetation	Paths & sidewalks	Slopes & ditches	Litter
11	2.7	17.4	20.0	0.6	18.4	19.2
12	.	10.3	9.9	0.8	10.3	19.6
21	3.6	18.3	19.1	0.6	18.8	19.5
22	1.4	17.7	19.2	1.0	18.6	20.0
31	1.6	19.3	19.4	0.7	19.8	19.6
32	1.2	19.8	20.0	0.5	19.8	20.2
41	1.8	18.2	18.0	.	18.2	18.2
42	.	9.8	9.8	0.2	9.8	10.0
43	2.4	19.7	19.6	0.1	19.6	19.6
51	4.3	18.9	19.8	0.9	19.4	19.9
53	.	20.0	20.0	0.8	19.2	20.0

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TABLE 2:

**NUMBER OF STRUCTURES IN SURVEY FOR
TRAFFIC AND ROADSIDE MAINTENANCE ACTIVITIES**

Statewide	Crash barriers	Guide signs	Highway lighting	Traffic signals	Pavement symbols	Warning symbols	Roadside delineators	Drainage structures
Total	57	718	128	153	496	714	2846	703

Highway type	Crash barriers	Guide signs	Highway lighting	Traffic signals	Pavement symbols	Warning symbols	Roadside delineators	Drainage structures
NHS	35	254	24	24	163	199	1678	256
OFF	2	83	8	.	14	80	113	63
PRI	13	240	66	123	226	249	736	203
SEC	7	112	12	4	13	158	287	161
URB	.	29	18	2	80	28	32	20

Maintenance division	Crash barriers	Guide signs	Highway lighting	Traffic signals	Pavement symbols	Warning symbols	Roadside delineators	Drainage structures
11	.	106	15	.	23	46	411	85
12	11	38	1	.	51	62	388	53
21	2	93	7	5	6	19	358	30
22	9	117	31	89	180	153	240	87
31	6	43	23	27	39	82	236	72
32	6	54	11	.	45	66	207	59
41	.	35	.	.	.	27	178	54
42	2	83	9	24	77	74	135	53
43	.	68	11	4	16	30	164	65
51	11	26	17	4	23	143	290	81
53	10	55	3	.	36	12	239	64

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TABLE 3:

STATEWIDE MAINTENANCE ACTIVITY ESTIMATES

ROADSIDE Maintenance Activities		Estimate	s.e.	95% CI	
1.	% drainage structures acceptable	69.1	2.6	64.2	74.6
2.	% fencing acceptable	98.7	0.4	97.9	99.4
3.	% mowing acceptable	60.7	2.0	56.8	64.4
4.	% nuisance vegetation acceptable	99.0	0.2	98.6	99.3
5.	% paths and sidewalks acceptable	94.0	3.0	88.3	99.0
6.	% slopes and ditches acceptable	95.3	0.7	94.0	96.6
7.	pieces of litter per mile	16.6	1.6	14.3	20.4

ROADWAY Maintenance Activities		Estimate	s.e.	95% CI	
8.	pieces of debris per mile	5.8	1.0	4.2	7.9
9.	% of roadway swept	93.7	0.9	91.7	95.3

TRAFFIC Maintenance Activities		Estimate	s.e.	95% CI	
10.	% crash barriers acceptable	85.4	5.5	73.7	94.8
11.	% guide signs acceptable	89.6	1.8	86.1	92.8
12.	% highway lighting acceptable	92.6	4.3	81.7	98.9
13.	% traffic signals acceptable	96.3	4.2	83.0	100.0
14.	% pavement symbols acceptable	75.8	4.3	66.9	83.3
15.	% protective barriers acceptable	98.2	0.5	96.8	98.9
16.	% regulatory & warning symbols acceptable	90.5	1.5	87.7	93.5
17.	% roadside delineators acceptable	85.7	1.4	82.5	87.9
18a.	% right striping acceptable (w/o refl)	90.7	1.1	88.4	92.6
19a.	% center striping acceptable (w/o refl)	86.4	1.4	83.7	89.1
20a.	% left striping acceptable (w/o refl)	88.9	1.1	86.6	91.0
18b.	% right striping acceptable (w/ refl)	74.6	1.7	47.8	55.4
19b.	% center striping acceptable (w/ refl)	51.5	1.9	71.4	77.6
20b.	% left striping acceptable (w/ refl)	67.9	1.9	64.4	71.7

TABLE 4:
ROADSIDE AND ROADWAY
MAINTENANCE ACTIVITY ESTIMATES BY HIGHWAY TYPE
(with standard errors)

	NHS	OFF	PRI	SEC	URB
% drainage structures acceptable	71.9 (3.9)	53.4 (9.5)	70.9 (4.7)	67.9 (5.7)	89.9 (7.0)
% fencing acceptable	98.7 (0.4)	. .	. .	. .	. .
% mowing acceptable	65.9 (3.1)	60.2 (6.6)	56.8 (4.0)	54.5 (4.3)	100 (0)
% nuisance vegetation acceptable	99.4 (0.3)	97.6 (0.9)	98.5 (0.5)	99.3 (0.3)	99.7 (0.2)
% paths and sidewalks acceptable	100 (0)	92.5 (3.6)	96.3 (3.6)	68.2 (0)	97.4 (2.0)
% slopes and ditches acceptable	95.8 (1.0)	94.9 (2.8)	92.7 (1.6)	97.3 (0.9)	100 (0)
pieces of litter per mile	22.1 (2.9)	5.6 (0.8)	10.2 (1.4)	15.4 (2.3)	152.8 (98.4)
pieces of debris per mile	4.6 (0.8)	0.7 (0.2)	10.4 (3.9)	5.6 (1.5)	7.6 (1.5)
% of roadway swept	91.4 (1.8)	90.2 (3.2)	93.5 (1.8)	99.6 (0.2)	85.3 (7.5)

TABLE 5:

**TRAFFIC MAINTENANCE ACTIVITY ESTIMATES
BY HIGHWAY TYPE
(with standard errors)**

	NHS	OFF	PRI	SEC	URB
% crash barriers acceptable	83.4 (7.2)	100 (0)	79.0 (17.0)	100 (0)	. .
% guide signs acceptable	94.7 (1.4)	80.7 (10.2)	85.6 (3.0)	92.4 (3.1)	100 (0)
% highway lighting acceptable	80.3 (14.6)	100 (0)	95.2 (5.6)	100 (0)	89.6 (6.7)
% traffic signals acceptable	95.8 (1.9)	. .	96.2 (8.1)	100 (0)	100 (0)
% pavement symbols acceptable	84.4 (7.4)	57.1 (20.3)	71.6 (8.1)	68.2 (16.0)	72.8 (4.9)
% protective barriers acceptable	98.5 (0.4)	98.3 (0.9)	97.1 (2.2)	100 (0)	0 (0)
% regulatory and warning symbols acceptable	96.3 (1.3)	71.1 (11.3)	92.9 (2.1)	88.0 (2.4)	96.2 (2.5)
% roadside delineators acceptable	86.6 (2.1)	76.3 (6.7)	83.9 (2.1)	88.4 (2.6)	68.0 (5.7)
% right striping acceptable (w/o reflectivity)	93.4 (1.5)	91.5 (2.4)	81.8 (2.5)	93.8 (2.3)	96.0 (2.4)
% center striping acceptable (w/o reflectivity)	89.8 (2.5)	92.2 (2.6)	80.2 (3.3)	86.6 (2.6)	98.1 (1.3)
% left striping acceptable (w/o reflectivity)	92.1 (1.5)	93.4 (2.0)	78.7 (2.6)	91.2 (2.5)	99.1 (0.3)
% right striping acceptable (w/ reflectivity)	80.7 (2.6)	78.1 (5.0)	62.0 (3.7)	77.0 (3.4)	0 (0)
% center striping acceptable (w/ reflectivity)	55.5 (3.1)	65.2 (6.0)	41.8 (3.2)	50.0 (3.9)	0 (0)
% left striping acceptable (w/ reflectivity)	73.8 (2.9)	77.5 (5.6)	55.5 (3.7)	68.1 (4.0)	0 (0)

TABLE 6:

**ROADSIDE AND ROADWAY
MAINTENANCE ACTIVITY ESTIMATES BY DIVISION
(with standard errors)**

	11	12	21	22	31	32	41	42	43	51	53
% drainage structures acceptable	57.0 (6.6)	89.0 (6.3)	63.8 (9.2)	53.3 (11.1)	59.7 (10.0)	60.1 (6.8)	60.9 (8.8)	75.7 (7.8)	83.1 (5.1)	91.9 (3.8)	63.1 (5.6)
% fencing acceptable	95.5 (2.5)	. (0)	100 (0)	99.7 (0.3)	96.9 (2.9)	97.6 (1.4)	97.6 (2.2)	. (0)	99.4 (0.5)	99.7 (0.1)	. (0)
% mowing acceptable	64.4 (6.3)	86.5 (4.3)	69.6 (6.4)	50.6 (6.9)	68.4 (5.6)	59.8 (6.1)	29.8 (6.9)	36.7 (6.7)	53.4 (6.3)	63.2 (6.7)	77.8 (5.8)
% nuisance vegetation acceptable	99.9 (0.1)	93.7 (2.7)	99.5 (0.4)	99.2 (0.4)	99.6 (0.2)	99.8 (0.2)	96.4 (1.6)	99.4 (0.3)	100 (0)	98.7 (0.5)	98.9 (0.5)
% paths and sidewalks acceptable	95.8 (2.8)	100 (0)	100 (0)	91.0 (13.5)	99.7 (0.3)	100 (0)	. (0)	100 (0)	100 (0)	80.4 (9.6)	100 (0)
% slopes and ditches acceptable	96.5 (1.5)	97.4 (2.2)	93.3 (2.5)	87.4 (3.5)	96.9 (2.2)	98.8 (1.0)	90.9 (3.0)	99.9 (0.1)	99.1 (0.5)	98.5 (0.9)	89.9 (3.1)
pieces of litter per mile	10.5 (2.1)	1.6 (0.9)	16.9 (6.8)	7.4 (1.7)	8.8 (0.8)	15.1 (2.6)	37.2 (4.6)	36.2 (19.6)	12.4 (2.7)	29.5 (5.6)	11.8 (3.0)
pieces of debris per mile	0.8 (0.4)	4.2 (3.4)	1.8 (0.8)	37.8 (10.4)	4.8 (1.5)	2.3 (0.6)	0.6 (0.3)	1.2 (0.4)	1.3 (0.4)	4.6 (1.2)	6.5 (1.6)
% of roadway swept	94.9 (2.8)	96.0 (2.4)	89.6 (4.0)	90.0 (3.4)	89.2 (3.6)	92.5 (3.5)	96.0 (2.8)	89.8 (4.0)	96.7 (2.3)	100 (0)	97.9 (1.9)

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TABLE 7:

**TRAFFIC MAINTENANCE ACTIVITY ESTIMATES
BY DIVISION (with standard errors)**

	11	12	21	22	31	32	41	42	43	51	53
% crash barriers acceptable	. (.)	100 (0)	100 (0)	89.0 (14.7)	83.3 (9.4)	100 (0)	. (.)	100 (0)	. (.)	81.4 (14.8)	49.5 (23.3)
% guide signs acceptable	95.0 (2.4)	99.1 (1.1)	87.0 (6.1)	76.9 (4.7)	97.7 (3.4)	93.0 (3.4)	90.6 (4.7)	91.8 (4.7)	94.1 (3.9)	95.7 (3.8)	81.2 (5.9)
% highway lighting acceptable	100 (0)	100 (0)	100 (0)	100 (0)	63.2 (14.6)	100 (0)	. (.)	100 (0)	100 (0)	97.2 (8.5)	100 (0)
% traffic signals acceptable	. (.)	. (.)	60.0 (0)	100 (0)	96.3 (1.8)	. (.)	. (.)	100 (0)	50.0 (0)	100 (0)	. (.)
% pavement symbols acceptable	71.0 (8.6)	100 (0)	0.0 (0)	77.7 (9.2)	70.8 (12.9)	32.5 (16.5)	. (.)	78.1 (11.4)	68.8 (15.0)	84.4 (12.1)	80.6 (0)
% protective barriers acceptable	99.3 (0.3)	100 (0)	99.6 (0.6)	97.8 (1.6)	95.8 (6.5)	94.1 (3.2)	100 (0)	100 (0)	98.4 (0.6)	96.8 (2.5)	90.7 (13.8)
% regulatory and warning symbols acceptable	89.3 (4.3)	99.5 (0.5)	89.1 (14.5)	82.7 (8.0)	91.4 (3.8)	94.9 (3.5)	88.0 (10.9)	86.5 (4.3)	90.0 (5.9)	94.1 (2.4)	90.8 (9.9)
% roadside delineators acceptable	79.3 (5.3)	94.9 (1.5)	85.7 (1.8)	72.2 (3.8)	84.9 (5.7)	83.9 (5.0)	93.3 (2.0)	95.5 (2.1)	92.1 (2.1)	84.2 (4.2)	89.2 (4.3)
% right striping acceptable (w/o reflectivity)	94.0 (1.9)	91.9 (3.8)	91.2 (3.2)	79.8 (4.0)	92.7 (3.3)	96.4 (1.9)	80.6 (5.0)	88.7 (4.1)	94.8 (1.7)	94.6 (3.8)	87.9 (3.7)
% center striping acceptable (w/o reflectivity)	84.0 (6.0)	88.3 (4.9)	89.8 (3.0)	85.7 (4.1)	87.8 (6.6)	95.0 (2.4)	27.0 (7.3)	92.0 (3.8)	99.6 (0.4)	97.1 (2.7)	86.7 (4.9)
% left striping acceptable (w/o reflectivity)	94.8 (1.7)	89.2 (3.9)	85.8 (3.7)	81.5 (3.7)	93.4 (3.0)	96.4 (1.9)	69.1 (5.9)	86.0 (4.4)	96.0 (1.6)	94.8 (3.7)	84.5 (4.3)
% right striping acceptable (w/ reflectivity)	63.4 (6.6)	88.4 (4.6)	85.2 (4.7)	49.8 (6.3)	90.7 (3.6)	76.8 (5.7)	75.8 (6.0)	68.0 (6.2)	59.2 (6.5)	75.8 (5.8)	83.1 (5.0)
% center striping acceptable (w/ reflectivity)	48.2 (6.7)	88.9 (4.4)	79.5 (5.5)	24.4 (5.2)	88.7 (4.0)	49.7 (7.0)	31.8 (6.6)	16.1 (5.4)	20.4 (6.0)	52.6 (6.8)	50.7 (6.5)
% left striping acceptable (w/ reflectivity)	62.1 (6.6)	79.8 (6.0)	77.2 (5.8)	43.8 (6.3)	86.8 (4.3)	69.0 (6.5)	63.9 (6.7)	62.1 (6.3)	59.2 (6.6)	62.5 (6.9)	81.1 (5.1)

11 = Missoula
12 = Kalispell
21 = Butte

22 = Bozeman
31 = Great Falls
32 = Havre

41 = Glendive
42 = Wolf Point
43 = Miles City

51 = Billings
53 = Lewistown

TABLE 8:

**95% CONFIDENCE INTERVAL ESTIMATES
BY HIGHWAY TYPE
FOR ROADSIDE AND ROADWAY MAINTENANCE ACTIVITIES**

	NHS	OFF	PRI	SEC	URB
% drainage structures acceptable	64.4 79.7	35.1 71.7	61.1 79.3	55.9 77.4	75.7 100
% fencing acceptable	97.9 99.4	..	..	..	..
% mowing acceptable	59.6 71.9	47.0 72.2	48.7 64.2	46.0 63.0	. .
% nuisance vegetation acceptable	98.8 99.8	95.6 99.1	97.4 99.4	98.7 99.7	99.4 100
% paths and sidewalks acceptable	. .	90.8 100	88.0 99.9	. .	92.9 100
% slopes and ditches acceptable	93.7 97.6	89.0 99.5	89.5 95.6	95.4 98.9	. .
pieces of litter per mile	17.1 28.4	4.2 7.3	7.6 13.1	11.2 20.0	11.2 295.2
pieces of debris per mile	3.2 6.2	0.3 1.1	4.3 18.8	3.0 8.8	4.8 10.6
% of roadway swept	87.7 94.7	83.5 96.1	89.8 96.9	99.2 99.9	70.5 100

TABLE 9:

**95% CONFIDENCE INTERVAL ESTIMATES
BY HIGHWAY TYPE
FOR TRAFFIC MAINTENANCE ACTIVITIES**

	NHS	OFF	PRI	SEC	URB
% crash barriers acceptable	68.9 96.7	. .	40.0 100	..	..
% guide signs acceptable	91.9 97.3	58.6 97.1	79.5 91.2	85.0 98.0	. .
% highway lighting acceptable	48.9 100	. .	80.5 100	. .	76.7 100
% traffic signals acceptable	95.7 100	. .	65.8 100	..	..
% pavement symbols acceptable	66.5 96.7	0 100	50.7 82.7	34.2 100	63.6 82.0
% protective barriers acceptable	97.5 99.3	97.7 100	91.5 99.7	..	..
% regulatory and warning symbols acceptable	93.1 98.5	47.2 91.4	88.6 96.4	82.9 93.4	91.3 100
% roadside delineators acceptable	82.5 90.2	63.1 88.6	79.5 87.7	83.1 93.3	59.5 81.8
% right striping acceptable (w/o reflectivity)	90.4 96.3	86.5 96.3	76.6 86.4	88.7 97.5	91.4 99.2
% center striping acceptable (w/o reflectivity)	84.5 94.6	87.0 97.0	74.0 86.2	81.3 91.5	95.6 100
% left striping acceptable (w/o reflectivity)	89.1 95.1	89.1 97.2	73.2 83.4	85.7 95.6	98.0 99.1
% right striping acceptable (w/ reflectivity)	49.2 61.2	55.6 79.0	35.4 48.2	42.5 57.2	. .
% center striping acceptable (w/ reflectivity)	75.4 85.3	67.6 87.5	54.8 69.3	70.1 83.3	. .
% left striping acceptable (w/ reflectivity)	67.5 79.0	65.7 87.8	48.4 62.6	60.3 75.7	. .

TABLE 10:
95% CONFIDENCE INTERVAL ESTIMATES
BY DIVISION
FOR ROADSIDE AND ROADWAY MAINTENANCE ACTIVITIES

	11	12	21	22	31	32	41	42	43	51	53
% drainage structures acceptable	45.6 71.2	74.4 98.8	46.5 81.2	30.4 73.6	38.9 77.3	46.6 73.8	43.6 76.4	59.9 89.8	72.9 92.6	82.5 97.5	51.9 73.4
% fencing acceptable	90.0 99.5	. .	. .	99.1 100	90.3 100	94.8 100	92.6 100	. .	98.3 100	99.3 99.9	. .
% mowing acceptable	52.0 76.6	77.0 93.7	56.8 80.8	37.5 63.9	58.4 80.0	48.0 71.4	16.6 43.2	23.9 50.1	41.0 64.8	50.4 76.1	65.5 88.1
% nuisance vegetation acceptable	99.6 100	88.1 98.1	98.7 100	98.5 99.9	99.1 100	99.4 100	92.8 98.9	98.7 99.9	99.9 100	97.7 99.7	97.7 99.8
% paths and sidewalks acceptable	90.8 100	. .	. .	47.7 100	98.8 100	. .	. .	. .	. .	73.2 100	. .
% slopes and ditches acceptable	93.2 99.1	92.5 100	88.0 97.7	80.4 94.0	91.8 99.7	96.7 100	84.8 96.4	99.7 100	97.9 99.9	96.3 99.8	82.9 95.4
pieces of litter per mile	6.3 14.8	0.1 3.7	10.4 33.7	4.6 11.1	7.2 10.4	10.5 20.9	29.1 47.0	9.1 79.2	8.1 18.0	19.4 41.0	6.5 18.4
pieces of debris per mile	0.1 1.7	0.0 11.7	0.5 3.4	20.8 60.2	2.3 8.1	1.2 3.5	0.1 1.4	0.5 2.1	0.7 2.0	2.6 7.3	3.8 10.2
% of roadway swept	89.4 99.5	90.6 99.7	81.1 96.6	82.5 96.0	81.2 95.3	84.9 98.6	89.9 100	80.5 97.2	91.9 100	. .	93.8 100

11 = Missoula	31 = Great Falls	43 = Miles City
12 = Kalispell	32 = Havre	51 = Billings
21 = Butte	41 = Glendive	53 = Lewistown
22 = Bozeman	42 = Wolf Point	

TABLE 11:

**95% CONFIDENCE INTERVAL ESTIMATES BY DIVISION
FOR TRAFFIC MAINTENANCE ACTIVITIES**

	11	12	21	22	31	32	41	42	43	51	53
% crash barriers acceptable	. . .	50.4	75.0	. . .	42.9	16.4	. . .	100	100	. . .	100
% guide signs acceptable	89.7	96.0	74.2	68.1	88.3	85.4	80.7	83.0	85.4	87.0	71.0
	99.0	100	97.8	87.0	100	98.5	100	100	100	100	93.3
% highway lighting acceptable	. . .	38.5	. . .	100	. . .	66.7	. . .	100	. . .		
% traffic signals acceptable	. . .	95.7	. . .	100	. . .	. . .	. . .	. . .	. . .	. . .	. . .
% pavement symbols acceptable	63.6	. . .	50.5	33.3	22.3	. . .	72.1	64.3	66.7	. . .	
	100	. . .	89.7	100	80.7	. . .	100	100	100	. . .	
% protective barriers acceptable	98.8	. . .	97.7	94.0	83.0	91.9	. . .	97.7	90.9	55.1	
	99.8	. . .	100	100	98.6	100	. . .	100	100	100	
% regulatory and warning symbols acceptable	82.8	98.4	47.8	63.3	82.2	87.0	60.1	80.3	78.6	90.7	64.2
	100	100	100	93.9	96.8	100	100	96.4	100	99.2	100
% roadside delineators acceptable	69.3	91.5	81.6	64.8	71.9	75.2	89.2	90.8	87.5	75.5	79.8
	89.9	97.3	88.6	79.8	93.7	94.8	96.8	99.2	96.1	91.6	96.7
% right striping acceptable (w/o reflectivity)	90.1	83.9	84.4	72.4	85.4	92.1	69.9	79.6	91.0	86.0	80.6
	97.5	98.5	96.6	87.8	98.3	99.5	90.4	95.7	97.8	100	94.9
% center striping acceptable (w/o reflectivity)	71.6	77.4	83.7	76.4	74.0	89.6	13.9	82.6	98.6	91.2	76.9
	94.7	96.9	95.5	92.6	99.0	99.1	42.7	97.8	100	100	95.7
% left striping acceptable (w/o reflectivity)	91.0	81.4	78.2	74.2	87.0	92.3	56.9	76.2	92.4	87.1	75.8
	97.5	95.9	92.7	88.4	98.7	99.8	80.3	93.8	98.6	100	92.4
% right striping acceptable (w/ acceptable)	34.2	79.9	68.8	14.3	80.8	35.3	18.8	6.1	10.2	39.9	38.5
	60.3	97.5	89.9	34.5	94.7	62.7	45.2	28.0	33.3	65.8	64.6
% center striping acceptable (w/ acceptable)	51.3	78.9	76.2	37.4	82.9	64.3	64.0	55.9	44.4	64.5	73.1
	77.0	97.2	94.2	62.0	96.6	87.4	87.4	79.8	71.3	86.4	93.3
% left striping acceptable (w/ acceptable)	48.8	67.4	65.9	31.3	77.0	55.9	50.6	48.3	46.6	49.5	70.5
	74.2	91.0	87.8	56.2	94.6	81.5	77.1	74.2	71.1	76.2	91.3

11 = Missoula 22 = Bozeman 41 = Glendive 51 = Billings
 12 = Kalispell 31 = Great Falls 42 = Wolf Point 53 = Lewistown
 21 = Butte 32 = Havre 43 = Miles City

APPENDIX

In the Appendix, formulas and methods used to calculate estimates, standard errors, and confidence intervals will be given. There are three types of quantities to estimate: (1) percentages based on acceptable lengths and (2) percentages based on acceptable counts, and (3) means based on pieces per mile. Each of these three quantities were estimated statewide, by highway type, and by maintenance division (and formulas and methods will be presented for each).

A1: STATEWIDE ESTIMATES

Percentages based on acceptable lengths

Let P represent the statewide percentage of an acceptable length for a maintenance activity of interest (e.g., fencing). To estimate P , we first have to calculate the following two quantities for that maintenance activity:

$\hat{\mu}_t$ = the estimated mean number of feet surveyed per roadway segment

$\hat{\mu}_a$ = the estimated mean number of acceptable feet surveyed per roadway segment

Our statewide estimate of the percentage P will be denoted \hat{P} and is defined as

$$\hat{P} = \frac{\hat{\mu}_a}{\hat{\mu}_t} \times 100\%.$$

For example, suppose we are interested in estimating the percentage P of acceptable fencing statewide. From the data it was calculated that $\hat{\mu}_t = 217.5$ feet and $\hat{\mu}_a = 214.8$ feet. Thus, our estimate \hat{P} is

$$\hat{P} = \frac{214.8}{217.5} \times 100\% = 98.7\%,$$

i.e., on average there are 217.5 feet of fencing and 214.8 feet of acceptable fencing per .2 mile roadway segment, or, we estimate that 98.7% of fencing is acceptable statewide.

Percentages based on counts

Let P represent the percentage of structures statewide that are acceptable for a maintenance activity of interest (e.g., drainage structures). To estimate P , we first have to calculate the following two quantities associated with that maintenance activity:

$\hat{\mu}_t$ = the estimated mean number of structures per roadway segment

$\hat{\mu}_a$ = the estimated mean number of acceptable structures per roadway segment

Our statewide estimate of the percentage P will be denoted \hat{P} and is defined as

$$\hat{P} = \frac{\hat{\mu}_a}{\hat{\mu}_t} \times 100\%.$$

For example, suppose we are interested in estimating the percentage P of acceptable drainage structures statewide. From the data it was calculated that $\hat{\mu}_t = 1.247$ and $\hat{\mu}_a = 0.862$ drainage structures. Thus, our estimate \hat{P} is

$$\hat{P} = \frac{0.862}{1.247} \times 100\% = 69.1\%,$$

i.e., on average there are 1.247 structures and 0.882 acceptable structures per .2 mile roadway segment, or, we estimate that 69.1% of drainage structures are acceptable statewide.

Means based on pieces per mile

Let μ represent the mean (average) pieces per mile for a maintenance activity of interest (e.g., litter). To estimate μ , we first have to calculate the following two quantities associated with that maintenance activity:

$\hat{\mu}_t$ = the estimated mean number of feet surveyed per roadway segment

$\hat{\mu}_a$ = the mean pieces per roadway segment

Our statewide estimate of the mean μ will be denoted $\hat{\mu}$ and is defined as

$$\hat{\mu} = \frac{\hat{\mu}_a}{\hat{\mu}_t} \times 5280.$$

For example, suppose we are interested in estimating the mean μ number of pieces of litter per mile statewide. From the data it was calculated that $\hat{\mu}_t = 1980$ feet and $\hat{\mu}_a = 6.23$ pieces of litter. Thus, our estimate $\hat{\mu}$ is

$$\hat{\mu} = \frac{6.23}{1980} \times 5280\% = 16.6,$$

i.e., we estimate that there are 6.23 pieces of litter for every 1980 feet surveyed, or equivalently, there are 16.6 pieces of litter for every mile surveyed. (Note: assuming both sides of the roadway can be surveyed for litter, the maximum is 2112 feet per .2 mile segment).

Calculating statewide estimates of $\hat{\mu}_t$ and $\hat{\mu}_a$

For each highway type and maintenance division, we can calculate two sample means per roadway segment: a sample mean for the quantity acceptable per roadway

segment and a sample mean of the total amount surveyed per roadway segment. $\hat{\mu}_a$ and $\hat{\mu}_t$ are, respectively, weighted averages of these sample means. The weights correspond to the proportions of statewide centerline miles associated with each highway type and maintenance division combination. Thus,

$$\hat{\mu}_t = \sum_{i=1}^5 \sum_{j=1}^{11} p_{ij} \bar{x}_{ij} \qquad \hat{\mu}_a = \sum_{i=1}^5 \sum_{j=1}^{11} p_{ij} \bar{y}_{ij}$$

where p_{ij} is the actual statewide proportion of centerline miles for highway type i and maintenance division j . The values of p_{ij} are given in Table 12.

For percentages based on acceptable lengths:

\bar{x}_{ij} = the sample mean number of feet surveyed per roadway segment for highway type i and maintenance division j

\bar{y}_{ij} = the sample mean number of acceptable feet surveyed per roadway segment for highway type i and maintenance division j

For percentages based on counts:

\bar{x}_{ij} = the sample mean number of structures per roadway segment for highway type i and maintenance division j

\bar{y}_{ij} = the sample mean number of acceptable structures per roadway segment for highway type i and maintenance division j

For means based on pieces per mile

\bar{x}_{ij} = the sample mean number of feet surveyed per roadway segment for highway type i and maintenance division j

\bar{y}_{ij} = the sample mean number of pieces per roadway segment for highway type i and maintenance division j

Standard Errors and Confidence Intervals

Standard errors and confidence intervals were calculated using the bootstrap method. The steps of the bootstrap method are

1. Take subsamples with replacement from the data set of roadway segments for each highway type and maintenance division. The subsample corresponding to highway type i and maintenance division j will have the same number of roadway segments as the original sample. The sample comprised by combining all subsamples will be known as a bootstrap sample.

2. For each maintenance activity calculate the appropriate estimate (\hat{P} or $\hat{\mu}$) from the bootstrap sample. These estimates are known as bootstrap replicates.
3. Repeat these first two steps 1000 times so that 1000 bootstrap replicates (of \hat{P} or $\hat{\mu}$) are generated for each maintenance activity.
4. For each maintenance activity:
 - (a) Calculate the sample standard deviation of the 1000 \hat{P} or $\hat{\mu}$ values. This value is known as the bootstrap standard error which is denoted $s.e.(\hat{P})$ or $s.e.(\hat{\mu})$.
 - (b) Put the 1000 \hat{P} or $\hat{\mu}$ values in increasing order. Take the 26th and 975th values in the ordered list. These values represent the lower and upper 95% confidence interval values (because 95% of the 1000 values fall between these two values).

A2: ESTIMATES BY HIGHWAY TYPE

In this section, estimation is restricted to be within each of the five highway types. We will be using the same estimation methods given in section A1 but applying them only to data associated with any one of the highway types. We will use i to represent a highway type. That is i will represent NHS, OFF, PRI, SEC, or URB.

Percentages based on acceptable lengths

Let P_i represent the percentage of an acceptable length for a maintenance activity of interest (e.g., mowing) within highway type i . To estimate P_i , we first have to calculate the following two quantities for that maintenance activity:

$\hat{\mu}_{it}$ = the estimated mean number of feet surveyed per roadway segment for highway type i

$\hat{\mu}_{ia}$ = the estimated mean number of acceptable feet surveyed per roadway segment for highway type i

Our highway type estimate of P_i will be denoted \hat{P}_i and is defined as

$$\hat{P}_i = \frac{\hat{\mu}_{ia}}{\hat{\mu}_{it}} \times 100\%.$$

For example, suppose we are interested in estimating the percentage P_{NHS} of acceptable mowing for the NHS highway type. From the data it was calculated that $\hat{\mu}_{it} = 1854$ feet and $\hat{\mu}_{ia} = 1222$ feet. Thus, our estimate \hat{P}_{NHS} is

$$\hat{P}_{NHS} = \frac{1222}{1854} \times 100\% = 65.9\%,$$

i.e., on average there are 1854 feet of mowing and 1222 feet of acceptable mowing per .2 mile of NHS roadway segment, or, we estimate that 65.9% of NHS mowing is acceptable.

Percentages based on counts

Let P_i represent the percentage of structures that are acceptable for a maintenance activity of interest (e.g., drainage structures) within highway type i . To estimate P_i , we first have to calculate the following two quantities associated with that maintenance activity:

$\hat{\mu}_{it}$ = estimated mean number of structures per roadway segment for highway type i

$\hat{\mu}_{ia}$ = estimated mean number of acceptable structures per roadway segment for highway type i

Our highway type estimate of P_i will be denoted \hat{P}_i and is defined as

$$\hat{P}_i = \frac{\hat{\mu}_{ia}}{\hat{\mu}_{it}} \times 100\%.$$

For example, suppose we are interested in estimating the percentage P_{NHS} of acceptable NHS drainage structures. From the data it was calculated that $\hat{\mu}_{it} = 1.077$ and $\hat{\mu}_{ia} = 0.774$ drainage structures. Thus, our estimate \hat{P}_{NHS} is

$$\hat{P}_{NHS} = \frac{0.774}{1.077} \times 100\% = 71.9\%,$$

i.e., on average there are 1.077 drainage structures and 0.774 acceptable drainage structures per .2 mile of NHS roadway segment, or, we estimate that 71.9% of NHS drainage structures are acceptable.

Means based on pieces per mile

Let μ_i represent the mean (average) pieces per mile for a maintenance activity of interest (e.g., litter) within highway type i . To estimate μ_i , we first have to calculate the following two quantities associated with that maintenance activity:

$\hat{\mu}_{it}$ = the estimated mean number of feet surveyed per roadway segment for highway type i

$\hat{\mu}_{ia}$ = the mean pieces per roadway segment for highway type i

Our highway type estimate of μ_i will be denoted $\hat{\mu}_i$ and is defined as

$$\hat{\mu}_i = \frac{\hat{\mu}_{ia}}{\hat{\mu}_{it}} \times 5280.$$

For example, suppose we are interested in estimating μ_{NHS} , the mean number of pieces of litter per mile for NHS roadway. From the data it was calculated that $\hat{\mu}_{it} = 1967$ feet and $\hat{\mu}_{ia} = 8.23$ pieces of litter. Thus, our estimate $\hat{\mu}_{NHS}$ is

$$\hat{\mu}_{NHS} = \frac{8.23}{1967} \times 5280\% = 22.1,$$

i.e., for NHS roadway, we estimate that there are 8.23 pieces of litter for every 1967 feet surveyed, or equivalently, there are 22.1 pieces of litter for every mile surveyed.

Calculating estimates of $\hat{\mu}_{it}$ and $\hat{\mu}_{ia}$ by highway type

For highway type i , we can calculate two sample means per roadway segment for each maintenance division: a sample mean quantity acceptable per roadway segment and a sample mean of the total amount surveyed per roadway segment. $\hat{\mu}_{ia}$ and $\hat{\mu}_{it}$ are, respectively, weighted averages of these sample means. For highway type i , the weights correspond to the proportions of centerline miles associated with each maintenance division within highway type i . Thus,

$$\hat{\mu}_{it} = \sum_{j=1}^{11} h_{ij} \bar{x}_{ij} \qquad \hat{\mu}_{ia} = \sum_{j=1}^{11} h_{ij} \bar{y}_{ij}$$

where \bar{x}_{ij} and \bar{y}_{ij} are the same sample means described in section A1. The weight h_{ij} is the proportion of centerline miles within highway type i corresponding to maintenance division j . The values of h_{ij} are given in Table 12.

Standard Errors and Confidence Intervals

Suppose we want standard errors and confidence intervals for P_i or μ_i for highway type i . Standard errors and confidence intervals were calculated using the bootstrap method. The steps of the bootstrap method are

1. Take subsamples with replacement from the data set of roadway segment for each maintenance division within highway type i . The subsample corresponding to maintenance division j will have the same number of roadway segments as the original sample. The sample comprised by combining all maintenance division subsamples within highway type i will be known as a bootstrap sample.
2. For each maintenance activity calculate the appropriate estimate (\hat{P}_i or $\hat{\mu}_i$) from the bootstrap sample. These estimates are known as bootstrap replicates.
3. Repeat these first two steps 1000 times so that 1000 bootstrap replicates (of \hat{P}_i or $\hat{\mu}_i$) are generated for each maintenance activity.

4. For each maintenance activity:

- (a) Calculate the sample standard deviation of the 1000 \hat{P}_i or $\hat{\mu}_i$ values. This value is known as the bootstrap standard error which is denoted $\text{s.e.}(\hat{P}_i)$ or $\text{s.e.}(\hat{\mu}_i)$.
- (b) Put the 1000 \hat{P}_i or $\hat{\mu}_i$ values in increasing order. Take the 26th and 975th values in the ordered list. These values represent, respectively, the lower and upper 95% confidence interval values.

A3: ESTIMATES BY MAINTENANCE DIVISION

In this section, estimation is restrict to be within each of the eleven maintenance divisions. We will be using the same estimation methods given in section A2 except the roles of highway types and maintenance divisions will be switched. We will use j to represent a maintenance division. That is j will represent 11, 12, 21, 22, 31, 32, 41, 42, 43, 51, or 53.

Percentages based on acceptable lengths

Let P_j represent the percentage of an acceptable length for a maintenance activity of interest (e.g., mowing) for maintenance division j . To estimate P_j , we first have to calculate the following two quantities for that maintenance activity:

$\hat{\mu}_{jt}$ = the estimated mean number of feet surveyed per roadway segment for maintenance division j

$\hat{\mu}_{ja}$ = the estimated mean number of acceptable feet surveyed per roadway segment for maintenance division j

Our maintenance division estimate of P_j will be denoted \hat{P}_j and is defined as

$$\hat{P}_j = \frac{\hat{\mu}_{ja}}{\hat{\mu}_{jt}} \times 100\%.$$

For example, suppose we are interested in estimating the percentage P_{11} of acceptable mowing for the (Missoula) maintenance division 11. From the data it was calculated that $\hat{\mu}_{jt} = 1820$ feet and $\hat{\mu}_{ja} = 1172$ feet. Thus, our estimate \hat{P}_{11} is

$$\hat{P}_{11} = \frac{1172}{1820} \times 100\% = 64.4\%,$$

i.e., on average there are 1820 feet of mowing and 1172 feet of acceptable mowing per .2 mile of Missoula division roadway segment, or, we estimate that 64.4% of mowing is acceptable for the Missoula division.

Percentages based on counts

Let P_j represent the percentage of structures that are acceptable for a maintenance activity of interest (e.g., drainage structures) for maintenance division j . To estimate P_j , we first have to calculate the following two quantities associated with that maintenance activity:

$\hat{\mu}_{jt}$ = the estimated mean number of structures per roadway segment for maintenance division j

$\hat{\mu}_{ja}$ = the estimated mean number of acceptable structures per roadway segment for maintenance division j

Our maintenance division estimate of P_j will be denoted \hat{P}_j and is defined as

$$\hat{P}_j = \frac{\hat{\mu}_{ja}}{\hat{\mu}_{jt}} \times 100\%.$$

For example, suppose we are interested in estimating the percentage P_{11} of acceptable Missoula division drainage structures. From the data it was calculated that $\hat{\mu}_{jt} = 1.65$ and $\hat{\mu}_{ja} = 0.94$ drainage structures. Thus, our estimate \hat{P}_{11} is

$$\hat{P}_{11} = \frac{0.94}{1.65} \times 100\% = 57.0\%,$$

i.e., on average there are 1.65 drainage structures and 0.94 acceptable drainage structures per .2 mile of Missoula division roadway segment, or, we estimate that 57.0% of Missoula division drainage structures are acceptable.

Means based on pieces per mile

Let μ_j represent the mean (average) pieces per mile for a maintenance activity of interest (e.g., litter) for maintenance division j . To estimate μ_j , we first have to calculate the following two quantities associated with that maintenance activity:

$\hat{\mu}_{jt}$ = the estimated mean number of feet surveyed per roadway segment for maintenance division j

$\hat{\mu}_{ja}$ = the mean pieces per roadway segment for maintenance division j

Our maintenance division estimate of μ_j will be denoted $\hat{\mu}_j$ and is defined as

$$\hat{\mu}_j = \frac{\hat{\mu}_{ja}}{\hat{\mu}_{jt}} \times 5280.$$

For example, suppose we are interested in estimating μ_{11} , the mean number of pieces of litter per mile for Missoula division roadway. From the data it was calculated that $\hat{\mu}_{jt} = 2013$ feet and $\hat{\mu}_{ja} = 4.01$ pieces of litter. Thus, our estimate $\hat{\mu}_{11}$ is

$$\hat{\mu}_{11} = \frac{4.01}{2013} \times 5280\% = 10.5,$$

i.e., for Missoula division roadway, we estimate that there are 4.01 pieces of litter for every 2013 feet surveyed, or equivalently, there are 10.5 pieces of litter for every mile surveyed.

Calculating estimates of $\hat{\mu}_{jt}$ and $\hat{\mu}_{ja}$ by maintenance division

For each maintenance division j , we can calculate two sample means per roadway segment for each highway type: a sample mean quantity acceptable per roadway segment and a sample mean of the total amount surveyed per roadway segment. $\hat{\mu}_{ja}$ and $\hat{\mu}_{jt}$ are, respectively, weighted averages of these sample means. For maintenance division j , the weights correspond to the proportions of centerline miles associated with each highway type within maintenance division j . Thus,

$$\hat{\mu}_{jt} = \sum_{i=1}^5 d_{ij} \bar{x}_{ij} \qquad \hat{\mu}_{ja} = \sum_{i=1}^5 d_{ij} \bar{y}_{ij}$$

where \bar{x}_{ij} and \bar{y}_{ij} are the same sample means described in section A1. A weight d_{ij} is the actual proportion of centerline miles within maintenance division j corresponding to highway type i . The values of d_{ij} are given in Table 12.

Standard Errors and Confidence Intervals

Suppose we want standard errors and confidence intervals for P_i or μ_i for maintenance division j . Standard errors and confidence intervals were calculated using the bootstrap method. The steps of the bootstrap method are

1. Take subsamples with replacement from the data set of roadway segment for each highway type within maintenance division j . The subsample corresponding to highway i will have the same number of roadway segments as the original sample. The sample comprised by combining all highway type subsamples within maintenance division j will be known as a bootstrap sample.
2. For each maintenance activity calculate the appropriate estimate (\hat{P}_j or $\hat{\mu}_j$) from the bootstrap sample. These estimates are known as bootstrap replicates.

3. Repeat these first two steps 1000 times so that 1000 bootstrap replicates (of \hat{P}_j or $\hat{\mu}_j$) are generated for each maintenance activity.
4. For each maintenance activity:
 - (a) Calculate the sample standard deviation of the 1000 \hat{P}_j or $\hat{\mu}_j$ values. This value is known as the bootstrap standard error which is denoted $\text{s.e.}(\hat{P}_j)$ or $\text{s.e.}(\hat{\mu}_j)$.
 - (b) Put the 1000 \hat{P}_j or $\hat{\mu}_j$ values in increasing order. Take the 26th and 975th values in the ordered list. These values represent, respectively, the lower and upper 95% confidence interval values.

TABLE 12:

WEIGHTS BASED ON CENTERLINE MILES

Highway type	Maint. division	Centerline miles	Weights		
			p_{ij}	d_{ij}	h_{ij}
NHS	11	576.6	0.048216	0.53838	0.11315
NHS	12	331.2	0.027696	0.39038	0.06499
NHS	21	681.8	0.057013	0.47001	0.13379
NHS	22	380.2	0.031793	0.36593	0.07461
NHS	31	425.8	0.035606	0.37582	0.08356
NHS	32	435.8	0.036442	0.34959	0.08552
NHS	41	401.6	0.033583	0.46129	0.07881
NHS	42	397.4	0.033231	0.38007	0.07798
NHS	43	364.8	0.030505	0.40678	0.07159
NHS	51	703.6	0.058836	0.45576	0.13807
NHS	53	397.2	0.033215	0.48844	0.07794
OFF	11	175.8	0.014701	0.16415	0.15688
OFF	12	15.6	0.001305	0.01839	0.01392
OFF	21	256.4	0.021441	0.17675	0.22881
OFF	22	44.0	0.003679	0.04235	0.03926
OFF	31	155.0	0.012961	0.13680	0.13832
OFF	32	75.0	0.006272	0.06016	0.06693
OFF	41	68.4	0.005720	0.07857	0.06104
OFF	43	74.6	0.006238	0.08318	0.06657
OFF	51	255.8	0.021390	0.16570	0.22827
PRI	11	176.8	0.014784	0.16508	0.06320
PRI	12	320.8	0.026826	0.37812	0.11468
PRI	21	281.8	0.023565	0.19426	0.10074
PRI	22	374.8	0.031341	0.36073	0.13398
PRI	31	218.4	0.018263	0.19276	0.07807
PRI	32	167.0	0.013965	0.13396	0.05970
PRI	41	213.2	0.017828	0.24489	0.07621
PRI	42	281.0	0.023498	0.26875	0.10045
PRI	43	329.0	0.027512	0.36686	0.11761
PRI	51	183.2	0.015320	0.11867	0.06549
PRI	53	251.4	0.021023	0.30915	0.08987
SEC	11	126.6	0.010587	0.11821	0.04445
SEC	12	177.2	0.014818	0.20886	0.06221
SEC	21	208.6	0.017444	0.14380	0.07324
SEC	22	228.4	0.019099	0.21983	0.08019
SEC	31	317.0	0.026508	0.27979	0.11130
SEC	32	566.2	0.047347	0.45420	0.19879
SEC	41	187.4	0.015671	0.21525	0.06580
SEC	42	367.2	0.030706	0.35119	0.12892
SEC	43	128.4	0.010737	0.14318	0.04508
SEC	51	377.6	0.031576	0.24459	0.13257
SEC	53	163.6	0.013681	0.20118	0.05744
URB	11	15.2	0.001271	0.01419	0.15768
URB	12	3.6	0.000301	0.00424	0.03734
URB	21	22.0	0.001840	0.01517	0.22822
URB	22	11.6	0.000970	0.01116	0.12033
URB	31	16.8	0.001405	0.01483	0.17427
URB	32	2.6	0.000217	0.00209	0.02697
URB	51	23.6	0.001973	0.01529	0.24481
URB	53	1.0	0.000084	0.00123	0.01037