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16. Abstract

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FINAL REPORT

FIELD EVALUATION OF HIGHWAY SAFETY HARDWARE MAINTENANCE GUIDELINES

by

Benjamin H. Cottrell, Jr.
Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
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Charlottesville, Virginia

January 1987
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ABSTRACT

The objective of this study was to evaluate with field tests, a procedure developed for the Federal Highway Administration for determining frequencies at which highway safety hardware needs to be inspected and repaired. The frequencies arrived at were based on the accident history of the safety hardware and the level of service to be provided, which is based on the probability of completing the inspection and repair before a subsequent accident. It was concluded that the procedure was a useful method for highway safety hardware maintenance guidelines. Some problems were noted and suggestions were made to resolve them.

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FINAL REPORT

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INTRODUCTION

Problem Statement

In 1984 there were 1,726 fixed-object accidents on interstate roads in Virginia in which vehicles struck highway safety hardware such as guardrails, sign and signal supports, and impact attenuators, and 1,785 such accidents on primary roads.[1] These figures represent 22.5 percent and 7.4 percent, respectively, of all accidents occurring on these types of roads. On the interstate roads, 26 (1.5 percent) of the fixed-object accidents involving highway safety hardware resulted in fatalities, 754 (43.7 percent) in injuries, and 946 (54.5 percent) in property damage. On the primary roads, 32 (1.8 percent) of the fixed-object accidents involving highway safety hardware resulted in fatalities, 802 (44.9 percent) in injuries, and 951 (53.3 percent) in property damage.

If struck and damaged by vehicles, highway safety hardware items can no longer fully perform their intended function, which is to protect motorists from identified hazards. Therefore, an adequate level of maintenance is required to preserve the functional integrity of the safety hardware.[2] This can be achieved by inspecting and repairing the hardware at intervals sufficiently frequently to maximize its safety benefits, subject to the available resources.

The sequence of events in the damage and repair of safety hardware is shown in figure 1. It is desired that the restoration time (t_r) be less than the time between accidents (t_a) for maximum safety.

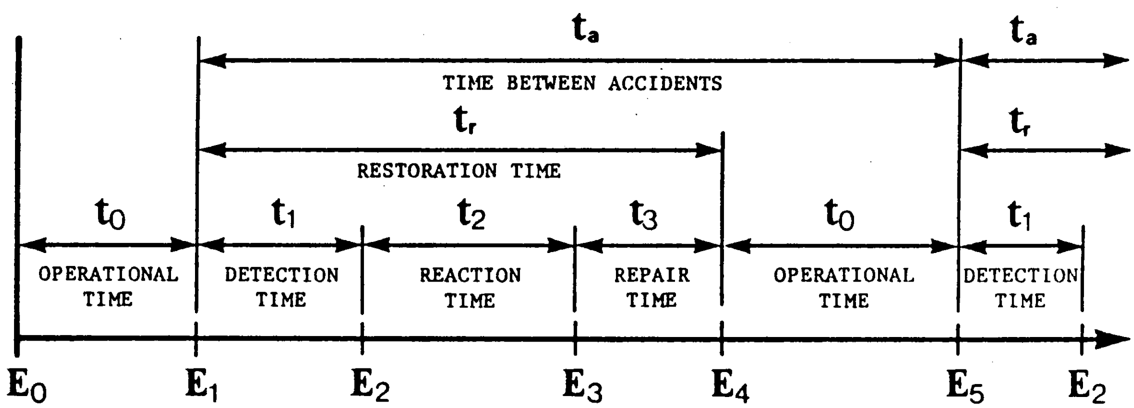

Figure 1. Sequence of events in damage and repair of highway safety hardware.

Legend

E_i = event i
E_0 = safety hardware installation
E_1 = accident involving safety hardware
E_2 = detection of damaged safety hardware
E_3 = repair work is begun
E_4 = repair work is completed
E_5 = subsequent accident involving safety hardware

Source: "A Method for Determining Frequencies for Inspection and Repair of Highway Safety Hardware"

A Method for Determining Inspection and Repair Frequencies

The Federal Highway Administration (FHWA) has developed a method for determining the frequencies at which safety hardware should be inspected and repaired.[2] The frequencies for the inspection and repair of hardware items are determined on the basis of the accident history of the items and the level of service to be provided, which is defined as the desired probability of completing the inspection and repair before a subsequent accident. The Poisson frequency distribution is used to statistically determine inspection and repair intervals.

Examples of the method are demonstrated using tables 1 and 2. If the average annual accident frequency is 2.0 and the probability of no accidents before completing a repair equals 0.95, then the repair must be completed in 9.4 days. For a lower confidence level of 0.90, the period for completion is 19.2 days.

> Assume that a maintenance planner must recommend inspection and repair intervals for a road segment having no notorious locations and an average of 2.5 accidents per year. Resources and other work allow repairs to be completed 3 days after detection and the district engineer wants to be nearly certain (0.999) that repairs will be completed before the next accident. Table 2 indicates that it cannot be done because the highest probability in the 2.5 average accidents column is 0.993 for detection and repair within 1 day. However, if the district engineer will accept high confidence (0.950), then a 7-day schedule can be proposed which will afford 0.973 confidence of detecting possible damage (completing the inspection within 4 days) and 0.953 assurance of restoration within the additional 3 days.[2]

This method is flexible in that it can be applied at different organizational levels, for different types of hardware, and for different classes of roads. Its versatility is exemplified by its usage for planning and managing the inspection and repair of safety hardware and other types of equipment, for preparing budgets, and for allocating funds. This method has much potential, but it has not been field tested.

TABLE 1

MAXIMUM INSPECTION OR RESTORATION TIME IN DAYS
(As a Function of Average Annual Accidents and Poisson Probabilities)

$$t = -\frac{365 \ln P(0)}{\overline{A}}$$

$\overline{A}$ Average Annual Accidents	P(0) = PROBABILITY OF NO ACCIDENTS 0.800	0.850	0.900	0.925	0.950	0.975	0.990	0.995	$\overline{A}$ Average Annual Accidents
0.2	407.2	296.6	192.3	142.3	93.6	46.2	18.3	9.1	0.2
0.4	203.6	148.3	96.1	71.1	46.8	23.1	9.2	4.6	0.4
0.6	135.7	98.9	64.1	47.4	31.2	15.4	6.1	3.0	0.6
0.8	101.8	74.1	48.1	35.6	23.4	11.6	4.6	2.3	0.8
1.0	81.4	59.3	38.5	28.5	18.7	9.2	3.7	1.8	1.0
1.2	67.9	49.4	32.0	23.7	15.6	7.7	3.1	1.5	1.2
1.4	58.2	42.4	27.5	20.3	13.4	6.6	2.6	1.3	1.4
1.6	50.9	37.1	24.0	17.8	11.7	5.8	2.3	1.1	1.6
1.8	45.2	33.0	21.4	15.8	10.4	5.1	2.0	1.0	1.8
2.0	40.7	29.7	19.2	14.2	[redacted]	4.6	1.8	0.9	2.0
2.2	37.0	27.0	17.5	12.9	8.5	4.2	1.7	0.8	2.2
2.4	33.9	24.7	16.0	11.9	7.8	3.9	1.5	0.8	2.4
2.6	31.3	22.8	14.8	10.9	7.2	3.6	1.4	0.7	2.6
2.8	29.1	21.2	13.7	10.2	6.7	3.3	1.3	0.7	2.8
3.0	27.1	19.8	12.8	9.5	6.2	3.1	1.2	0.6	3.0
3.2	25.5	18.5	12.0	8.9	5.9	2.9	1.1	0.6	3.2
3.4	24.0	17.4	11.3	8.4	5.5	2.7	1.1	0.5	3.4
3.6	22.6	16.5	10.7	7.9	5.2	2.6	1.0	0.5	3.6
3.8	21.4	15.6	10.1	7.5	4.9	2.4	1.0	0.5	3.8
4.0	20.4	14.8	9.6	7.1	4.7	2.3	0.9	0.5	4.0
4.2	19.4	14.1	9.2	6.8	4.5	2.2	0.9	0.4	4.2
4.4	18.5	13.5	8.7	6.5	4.3	2.1	0.8	0.4	4.4
4.6	17.7	12.9	8.4	6.2	4.1	2.0	0.8	0.4	4.6
4.8	17.0	12.4	8.0	5.9	3.9	1.9	0.8	0.4	4.8
5.0	16.3	11.9	7.7	5.7	3.7	1.8	0.7	0.4	5.0
5.2	15.7	11.4	7.4	5.5	3.6	1.8	0.7	0.4	5.2
5.4	15.1	11.0	7.1	5.3	3.5	1.7	0.7	0.3	5.4
5.6	14.5	10.6	6.9	5.1	3.3	1.7	0.7	0.3	5.6
5.8	14.0	10.2	6.6	4.9	3.2	1.6	0.6	0.3	5.8
6.0	13.6	9.9	6.4	4.7	3.1	1.5	0.6	0.3	6.0
6.2	13.1	9.6	6.2	4.6	3.0	1.5	0.6	0.3	6.2
6.4	12.7	9.3	6.0	4.4	2.9	1.4	0.6	0.3	6.4
6.6	12.3	9.0	5.8	4.3	2.8	1.4	0.6	0.3	6.6
6.8	12.0	8.7	5.7	4.2	2.8	1.4	0.5	0.3	6.8
7.0	11.6	8.5	5.5	4.1	2.7	1.3	0.5	0.3	7.0
7.2	11.3	8.2	5.3	4.0	2.6	1.3	0.5	0.3	7.2
7.4	11.0	8.0	5.2	3.8	2.5	1.2	0.5	0.2	7.4
7.6	10.7	7.8	5.1	3.7	2.5	1.2	0.5	0.2	7.6
7.8	10.4	7.6	4.9	3.6	2.4	1.2	0.5	0.2	7.8
8.0	10.2	7.4	4.8	3.6	2.3	1.2	0.5	0.2	8.0
8.2	9.9	7.2	4.7	3.5	2.3	1.1	0.4	0.2	8.2
8.4	9.7	7.1	4.6	3.4	2.2	1.1	0.4	0.2	8.4
8.6	9.5	6.9	4.5	3.3	2.2	1.1	0.4	0.2	8.6
8.8	9.3	6.7	4.4	3.2	2.1	1.1	0.4	0.2	8.8
9.0	9.0	6.6	4.3	3.2	2.1	1.0	0.4	0.2	9.0
9.2	8.9	6.4	4.2	3.1	2.0	1.0	0.4	0.2	9.2
9.4	8.7	6.3	4.1	3.0	2.0	1.0	0.4	0.2	9.4
9.6	8.5	6.2	4.0	3.0	2.0	1.0	0.4	0.2	9.6
9.8	8.3	6.1	3.9	2.9	1.9	0.9	0.4	0.2	9.8
10.0	8.1	5.9	3.8	2.8	1.9	0.9	0.4	0.2	10.0

TABLE 2

POISSON PROBABILITIES FOR ZERO ACCIDENTS AS A FUNCTION OF AVERAGE NUMBER OF ACCIDENTS AND TIME

$$P(0) = e^{-\bar{A}t/365}$$

t Days Between Accidents	$\bar{A}$-AVERAGE ANNUAL ACCIDENT FREQUENCY																t Days Between Accidents
	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500	5.000	5.500	6.000	7.000	8.000	9.000	10.000	
1	0.999	0.997	0.996	0.995	0.993	0.992	0.990	0.989	0.988	0.986	0.985	0.984	0.981	0.978	0.976	0.973	1
2	0.997	0.995	0.992	0.989	0.986	0.984	0.981	0.978	0.976	0.973	0.970	0.968	0.962	0.957	0.952	0.947	2
3	0.996	0.992	0.988	0.984	0.980	0.976	0.972	0.968	0.964	0.960	0.956	0.952	0.944	0.936	0.929	0.921	3
4	0.995	0.989	0.984	0.978	0.973	0.968	0.962	0.957	0.952	0.947	0.942	0.936	0.926	0.916	0.906	0.896	4
5	0.993	0.986	0.980	0.973	0.966	0.960	0.953	0.947	0.940	0.934	0.927	0.921	0.909	0.896	0.884	0.872	5
6	0.992	0.984	0.976	0.968	0.960	0.952	0.944	0.936	0.929	0.921	0.914	0.906	0.891	0.877	0.862	0.848	6
7	0.990	0.981	0.972	0.962	0.953	0.944	0.935	0.926	0.917	0.909	0.900	0.891	0.874	0.858	0.841	0.825	7
8	0.989	0.978	0.968	0.957	0.947	0.936	0.926	0.916	0.906	0.896	0.886	0.877	0.858	0.839	0.821	0.803	8
9	0.988	0.976	0.964	0.952	0.940	0.929	0.917	0.906	0.895	0.884	0.873	0.862	0.841	0.821	0.801	0.781	9
10	0.986	0.973	0.960	0.947	0.934	0.921	0.909	0.896	0.884	0.872	0.860	0.848	0.825	0.803	0.781	0.760	10
11	0.985	0.970	0.956	0.942	0.927	0.914	0.900	0.886	0.873	0.860	0.847	0.835	0.810	0.786	0.762	0.740	11
12	0.984	0.968	0.952	0.936	0.921	0.906	0.891	0.877	0.862	0.848	0.835	0.821	0.794	0.769	0.744	0.720	12
13	0.982	0.965	0.948	0.931	0.915	0.899	0.883	0.867	0.852	0.837	0.822	0.808	0.779	0.752	0.726	0.700	13
14	0.981	0.962	0.944	0.926	0.909	0.891	0.874	0.858	0.841	0.825	0.810	0.794	0.765	0.736	0.708	0.681	14
15	0.980	0.960	0.940	0.921	0.902	0.884	0.866	0.848	0.831	0.814	0.798	0.781	0.750	0.720	0.691	0.663	15
16	0.978	0.957	0.936	0.916	0.896	0.877	0.858	0.839	0.821	0.803	0.786	0.769	0.736	0.704	0.674	0.645	16
17	0.977	0.954	0.933	0.911	0.890	0.870	0.850	0.830	0.811	0.792	0.774	0.756	0.722	0.689	0.658	0.628	17
18	0.976	0.952	0.929	0.906	0.884	0.862	0.841	0.821	0.801	0.781	0.762	0.744	0.708	0.674	0.642	0.611	18
19	0.974	0.949	0.925	0.901	0.878	0.855	0.833	0.812	0.791	0.771	0.751	0.732	0.695	0.659	0.626	0.594	19
20	0.973	0.947	0.921	0.896	0.872	0.848	0.825	0.803	0.781	0.760	0.740	0.720	0.681	0.645	0.611	0.578	20
21	0.972	0.944	0.917	0.891	0.866	0.841	0.818	0.794	0.772	0.750	0.729	0.708	0.668	0.631	0.596	0.563	21
22	0.970	0.942	0.914	0.886	0.860	0.835	0.810	0.786	0.762	0.740	0.718	0.697	0.656	0.617	0.581	0.547	22
23	0.969	0.939	0.910	0.882	0.854	0.828	0.802	0.777	0.753	0.730	0.707	0.685	0.643	0.604	0.567	0.533	23
24	0.968	0.936	0.906	0.877	0.848	0.821	0.794	0.769	0.744	0.720	0.697	0.674	0.631	0.591	0.553	0.518	24
25	0.966	0.934	0.902	0.872	0.843	0.814	0.787	0.760	0.735	0.710	0.686	0.663	0.619	0.578	0.540	0.504	25
26	0.965	0.931	0.899	0.867	0.837	0.808	0.779	0.752	0.726	0.700	0.676	0.652	0.607	0.566	0.527	0.491	26
27	0.964	0.929	0.895	0.862	0.831	0.801	0.772	0.744	0.717	0.691	0.666	0.642	0.596	0.553	0.514	0.477	27
28	0.962	0.926	0.891	0.858	0.825	0.794	0.765	0.736	0.708	0.681	0.656	0.631	0.585	0.541	0.501	0.464	28
29	0.961	0.924	0.888	0.853	0.820	0.788	0.757	0.728	0.699	0.672	0.646	0.621	0.573	0.530	0.489	0.452	29
30	0.960	0.921	0.884	0.848	0.814	0.781	0.750	0.720	0.691	0.663	0.636	0.611	0.563	0.518	0.477	0.440	30
35	0.953	0.909	0.866	0.825	0.787	0.750	0.715	0.681	0.650	0.619	0.590	0.563	0.511	0.464	0.422	0.383	35
40	0.947	0.896	0.848	0.803	0.760	0.720	0.681	0.645	0.611	0.578	0.547	0.518	0.464	0.416	0.373	0.334	40
45	0.940	0.884	0.831	0.781	0.735	0.691	0.650	0.611	0.574	0.540	0.508	0.477	0.422	0.373	0.330	0.291	45
50	0.934	0.872	0.814	0.760	0.710	0.663	0.619	0.578	0.540	0.504	0.471	0.440	0.383	0.334	0.291	0.254	50
55	0.927	0.860	0.798	0.740	0.686	0.636	0.590	0.547	0.508	0.471	0.437	0.405	0.348	0.300	0.258	0.222	55
60	0.921	0.848	0.781	0.720	0.663	0.611	0.563	0.518	0.477	0.440	0.405	0.373	0.316	0.268	0.228	0.193	60
90	0.884	0.781	0.691	0.611	0.540	0.477	0.422	0.373	0.330	0.291	0.258	0.228	0.178	0.139	0.109	0.085	90
120	0.848	0.720	0.611	0.518	0.440	0.373	0.316	0.268	0.228	0.193	0.164	0.139	0.100	0.072	0.052	0.037	120
180	0.781	0.611	0.477	0.373	0.291	0.228	0.178	0.139	0.109	0.085	0.066	0.052	0.032	0.019	0.012	0.007	180
365	0.607	0.368	0.223	0.135	0.082	0.050	0.030	0.018	0.011	0.007	0.004	0.002	0.001	0.000	0.000	0.000	365

Objective

The objective of this research was to evaluate, with field tests, the method developed for the FHWA.

The method was tested on five sites at which one or more of the following types of safety hardware had been installed: roadway barriers, bridge rails, impact attenuators, breakaway sign supports, and breakaway luminaire supports.

IDENTIFICATION OF HIGH HAZARD SITES

This section consists of three parts: (1) selection criteria and approach, (2) site description, and (3) instruction of maintenance personnel in field testing.

Site Selection Criteria and Approach

There were three selection criteria: (1) roadway sections 1 to 5 miles long, (2) average daily traffic (ADT) of 15,000 vehicles or more, and (3) four or more reported accidents per year involving highway safety hardware. Road sections 1 to 5 miles long were considered to provide an adequate amount of highway safety hardware while remaining manageable. Road sections with high ADT provide greater exposure to traffic for highway safety hardware, thereby providing more opportunities for accidents. Road sections with high accident experience have a greater probability of a second accident occurring before damaged hardware is repaired.

The identification and selection of sites took into consideration the following factors: the highest accident frequencies involving safety hardware, a broad range of average daily traffic volumes, no planned construction or maintenance activities that would affect the site, and the willingness of maintenance personnel to participate.

Description of Field Sites

A description of the five sites is provided in table 3. This description includes location, length, ADT, mean number of accidents involving highway safety hardware accidents per year for 1981-1983, roadway description, and an inventory of highway safety hardware.

Briefing of Maintenance Crew

Briefings were conducted with a maintenance supervisor during the trip to inventory highway safety hardware for each site. The briefing included an overview of the research effort, instructions on how to complete the inspection-and-repair reporting forms, and discussion on inspection and repair activities.

DATA COLLECTION PROCEDURE

The objective of the field test was to collect data on highway safety hardware inspection and repair activities at the five sites for one year in order to evaluate the highway safety hardware maintenance guidelines. A monthly inspection-and-repair report (figure 2) and a damage-and-repair report form (figure 3) were completed by the maintenance foreman responsible for inspection and repair at each site. The following information was collected on the forms.

-- The frequency of inspection and repair activities
-- The number of times the highway safety hardware was damaged by vehicle impact
-- The maintenance crew time in person-hours to maintain the safety hardware
-- The cost of materials and parts used to maintain the highway safety hardware

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Table 3 - Part 1

Description of the Field Sites

Site No.	Location	Length (miles)	1984 ADT	Mean Number of Highway Safety Hardware Accidents Per Year from 1981-1983
1	I-395, Part 1: from I-95 to Arlington Co. Line (Fairfax Co. and Alexandria)	5.30	121,020	62.3
2	I-395, Part 2: Arlington Co.	4.38	135,105	52.3
3	I-64 from Rt. 258 (Mercury Blvd.) to Rt. 167 (La Salle Ave.) Hampton	2.00	61,135	19.0
4	Rt. 50 Arlington County	5.20	46,765	12.0
5	Rt. 150 from Rt. 360 to Rt. 1	5.45	28,880	9.0

Notes:

1. The typical lane width is 12 ft. for Rt. 50; lane width varies from 11-12 ft.
2. With the exception of Rt. 50, all sites have a paved shoulder.
3. On the two sections of I-395, luminaire posts are located behind guardrail at a spacing of 160-200 ft.
4. Highway safety hardware on ramps to and from the test sections were not inventoried.

Table 3, Part 2

Description of the Field Sites

Location	Roadway Description	Guardrail, linear ft.	Bridge Rail, linear ft.	Concrete Barrier, linear ft.	No. of Impact Attenuators	No. of Ground-Mounted Signs exposed to traffic
I-395, Part 1	6 lanes with 2 reversible HOV lanes in the median	58,365	1,441		4	13
I-395, Part 2	6 lanes with 2 reversible HOV lanes in the median	19,130	4,995	16,900	9	5
I-64	4 lanes divided by grass	17,420	400	3,690	2	16
Rt. 50	6 lanes divided by guardrail; barrier with a short 4-lane undivided section	7,320	713	4,013	1	101
Rt. 150	4 lanes divided	37,940	5,600	0	0	32

Form 1

Inspection and Repair Report of
Highway Safety Hardware

Route_____ From____________________ To_______________________

Inspector___________________________

Monthly Report for ___________, 198__

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Legend

Example

1 I	I - Drive-through inspection, no problems reported.	7 RB	RB - Repair Begun
4 P	P - Problem noted during inspection (see problem Form 2)	9 RC	RC - Repair Completed
5 R	R - Report of damaged Safety Hardware received by inspector (see Form 2)	15 DI	DI - detailed close-up inspection

Figure 2. Inspection and Repair Report of Highway Safety Hardware

Form 2

HIGHWAY SAFETY HARDWARE DAMAGE AND REPAIR REPORT FORM

Route________ Side of Road - shoulder median both

Approach Direction - northbound southbound eastbound westbound HOV lane

Location____

Date______________________

Damage Report

1. How did you find out about the damage?

___ Inspection ___ Police report (Attach a copy)
___ Other Department employee ___ Citizen call in

2. How was the safety hardware damaged?

___ Vehicle impact ___ Other, (specify)____________________

3. Was the safety hardware already damaged before this report?

___ Yes ___ No

4. Describe the damaged safety hardware (please include the type of hardware and the extent of the damage).

5. When should the hardware be repaired?

___ Immediately ___ When schedule permits

Repair Report

6 - 8 If available, contract bid proposal sheets may be attached to this form for answers.

6. What was the total maintenance crew time in man-hours? __________

7. Describe what repairs were needed.

8. List the materials and parts needed and the quantity of materials and their cost.

Materials and Parts Quantity Cost

9. When was the repair work begun? ________________

10. When was the repair work completed?________________

Figure 3. Highway Safety Hardware Damage and Repair Report Form

- How the maintenance supervisor found out about the damage to highway safety hardware, the cause of the damage, and knowledge of previous damage
- When the damage is scheduled for repair and when the repair work began and was completed

ANALYSIS

The analysis of the data is divided into the following sections: inspection and repair activities, inspection schedule adherence, damage reporting, damage-and-repair report summary, and second accidents.

Inspection and Repair Activities

The highway safety hardware inspection and repair activities at the field sites are discussed below for each site.

Inspection

A summary of the inspection and damage reporting activities are shown in table 4.

The two study sites on I-395 and the Rt. 50 site were divided by highway safety hardware and traffic signs because they are maintained by different area headquarters. The reporting of damaged highway safety hardware on Interstate 395 and Rt. 50 depends very heavily on the police since the inspector only reported severely damaged guardrail.

Repair Activities

Traffic signs and impact attenuators (except on Rt. 50) are repaired immediately by departmental forces whereas guardrail damages are repaired on contract. Ground-mounted traffic signs are repaired during inspection whereas overhead signs are repaired by the district traffic staff.

Guardrail repair contracts are negotiated for each district. The description of the basic contract provisions is below.

> This work shall consist of replacing and installing guardrail and median barrier in reasonably close conformity with the existing lines and grades or as directed by the engineer. Minimum repair call will be 200 linear feet per city or county and repair operations shall begin within five (5) working days after notice is received. The contractor shall advise the engineer at least 24 hours prior to commencement of work. The contractor shall not begin work at any location until the location and extent of work has been verified and approved by the engineer or his representative.[5]

Where the Department does not have the capability to perform emergency guardrail repairs such as for Rt. 150 and Interstate 64, the following provision is added.

> The contractor will be expected to make an emergency response within twenty-four (24) hours for locations where emergency repairs of guardrail end sections and exposed guardrail sections are necessary.[5]

Table 4

Inspection and Repair Activities

Site No.	Site Description	Inspection Intervals	Repairer	Repair Frequency
1	I-395, hardware, Part 1	impact attenuator - 15 days	Department	Immediately
		guardrail - *	Contract	Scheduled
	I-395, signs, Part 2	3 days	Department	Immediately
2	I-395, hardware, Part 2	impact attenuator - 15 days	Department	Immediately
		guardrail - *	Contract	Scheduled
	I-395, signs, Part 2	3 days	Department	Immediately
3	I-64	5 days	Hardware-Contract Signs-Department	Scheduled Immediately
4	Rt. 50, hardware	hardware - *	Contract	Guardrail-Scheduled Impact attenuators-Immediately
	Rt. 50, signs	3 days	Department	Immediately
5	Rt. 150	4 days	Hardware-Contract Signs-Department	Scheduled Immediately

*Damage reporting is provided primarily by police, who make their reports in three ways: (1) dispatcher to dispatcher for emergencies (impact attenuator damage and severe guardrail damage), (2) road hazard report (sent immediately), (3) accident report. A maintenance foreman notes badly damaged hardware during inspection drives.

The minimum repair call of 200 linear feet is included to ensure that at least a full day's work in guardrail repair is requested. The objective is to maximize the productivity of the guardrail repair crew while minimizing the travel required between locations for one day.

Inspection Schedule Adherence

The degree to which the inspection and repair activities were completed within the expected time intervals was examined using the t-test, which is a comparison of an average inspection interval with the expected inspection interval.(6) The results of the two-sided test for significant difference with a level of confidence of $\alpha = 0.05$ are shown in table 5. Table 5 displays the inspection data based on calendar days. Since highway safety hardware is exposed to traffic seven days per week, calendar days were used in lieu of work days.

Table 5

Inspection Schedule Adherence

Part A: Inspection Intervals based on calendar days

Site	Average Inspection Interval, days	Expected Inspection Interval, Days
I-395, hardware, 1 & 2	14.60	15.0
I-395, signs, 1 & 2	2.86	3.0
I-64	4.70	4.5
Rt. 50, signs	2.72	2.5
Rt. 50	3.48	3.5

NOTE: No significant differences among the sites.

It was concluded that the inspection schedule was adhered to for all sites.

Damage Reporting

There are five sources noted for reporting highway safety hardware damage: (1) inspectors, (2) Departmental employees, (3) police, (4) citizens, and (5) other - any source not listed above. Table 6 displays the damage reporting by source for the field sites. It is noted that inspectors and police are the primary sources for damage reporting.

Table 6

Damage Reporting by Source

Location	Inspection Number (%)	VDOT Number (%)	Police Number (%)	Citizen Number (%)	Other Number (%)
I-395, hardware, 1	7[a](26)	0(0)	19(70)	0(0)	1(4)
I-395, hardware, 2	2[a](7)	0(0)	20(74)	0(0)	5(19)
I-395, signs, 1	10(100)	0(0)	0(0)	0(0)	0(0)
I-395, signs, 2	19(83)	2(9)	1(4)	1(4)	0(0)
I-64	4[b](57)	0(0)	5[b](71)	0(0)	0(0)
Rt. 50, signs	66(96)	2(3)	1(1)	0(0)	0(0)
Rt. 50, hardware	0(0)	0(0)	6(75)	0(0)	2(25)
Rt. 150	25(96)	1(4)	0(0)	0(0)	0(0)

[a] Impact attenuators were the only safety hardware reported damaged during inspection.
[b] Two damage reports cited both inspection and police as sources.

Since locations I-395 (hardware, 1 and 2) and Rt. 50 (hardware) depend heavily on police reporting, the time between the accident and receipt of the damage report by the Department was examined. The average detection time for I-395 was 7.3 days with a standard deviation of 5.5 days and a range of 2-11 days. Reports by the State Police and Arlington County Police took an average of 7.3 days and 4.0 days, respectively. For Route 50, the average detection time for reporting from Arlington County Police was 3.3 days (range 2-5 days).

Damage and Repair Report Summary

Damage-and-repair report summaries are provided in Appendix A for each study site. The information was provided from figure 2 or from accident reports, road hazard reports, and/or residency daily cost reports. Although one-hundredth of a mile is the basic unit in Virginia, one-tenth of a mile was chosen as the basic unit to represent the typical agency as noted in the procedure.(2) Since the damage and repair activities differ with signs and highway safety hardware, these two categories are discussed separately.

Traffic Signs

Traffic signs were repaired immediately when the damages were noted during inspection. Therefore, the reaction time and repair time in days equal 0. In most instances, the location of the damaged traffic sign was provided with reference to intersecting streets or ramps without noting specific distances relative to these locations. Therefore, most locations were listed at the nearest intersection or ramp. One inspector was responsible for maintaining all three road sections. For Rt. 50 and I-395 from Rt. 7 to Washington, D.C., part 2, over 96 percent of the damages were a result of vehicle impact. On the other section of I-395, over half of the repairs were made as sign replacement for routine maintenance.

Since there was no way to identify second accidents occurring before detection and repair, no further evaluation of the procedure was possible relative to the prediction of second accidents.

Safety Hardware

The mean number of days from the damage report to repair ranged from 26 to 121 days for all repairs, and from 32 to 121 days for contract repair only (see table 7). Such long intervals would appear to result in a high potential for second accidents before repair. However, on I-64, with the longest mean reaction time, there were no second accidents reported. It is noted that on Rt. 150, the mean reaction time is low because over 60 percent of the damages were unrepaired at the end of the monitoring period.

Table 7

Reaction Time and Time Between Hits

Site	Reaction Time, days		Time Between Hits, days	
	Mean	Std. Dev.	Mean	Std. Dev.
I-395, hardware 1	26	19	72	57
I-395, hardware 2	33	27	91	90
I-64	121	56	434	40
Rt. 50, hardware	33	24		
Rt. 150	42	34	81	73

Table 7 shows that mean time between hits is greater than the mean reaction time for each site. Moreover, the mean time between hits is greater than the restoration time, which is the sum of the detection, reaction, and repair times. Nevertheless, one or more accidents before repair were noted at eight locations on three study sections.

The long restoration time period may be explained by the fact that contract guardrail repair work was not initiated until there were 200 linear feet of damaged guardrail in a county, and the fact that the contractor's guardrail repair crews were severely understaffed and were unable to respond to the repair request within the 5 working days as stated in the contract. The latter is a major problem on Route 150.

The mean repair time was less than one day for all sites. It is apparent from tables 5 and 7 that the reaction time is the longest time period in the restoration time.

Second Accidents

The ability of the procedure to predict second accidents is important because the inspection and restoration intervals are determined by the probability of a second accident not occurring before repair is completed.

The expected and actual number of second accidents are statistically compared using the Wilcoxon matched-pairs signed-rank test with a level of significance of 0.05 for a one-sided test.(6) The conclusion drawn from each of the sets of data from the five field sites was that the actual number of second accidents was significantly lower than the expected number of second accidents. In fact, if rounded up to the nearest integer, the expected number of second accidents is equal to the average annual number of accidents.

This conclusion is significant because the method for determining inspection and repair intervals is based on the probability of a second accident occurring. In one respect, it may be concluded that a safety margin is provided by overestimating the number of second accidents: the overestimation attempts to account for the worst conditions. It is clear that the method does not adequately predict second accidents, and that even with a statistical procedure, it is difficult to predict accidents.

FOLLOWING THE METHOD

Five steps are suggested for applying the method. Each step is mentioned below and discussed in detail in the appendix.

1. Obtain the frequency data on traffic accidents involving highway safety hardware.

   The 1-year monitoring of inspection and repair activities provided these data in lieu of Department traffic accident records or special studies. In fact, the monitoring may be considered a special study. The monitoring identifies reported and unreported accidents involving highway safety hardware.

2. Rank accident locations in decreasing order of average annual safety hardware accidents.

3. Sort the locations by road class and identify accident groups (by similar accident frequencies).

   Steps 2 and 3 were performed together using Lotus 1-2-3 microcomputer software functions. The results are shown in tables 8 and 9 in which the locations are divided into 4 and 5 groups, respectively.

4. Identify the range of inspection and restoration intervals for each group.

   The range of inspection and repair intervals are shown in table 10. The procedure to develop the ranges is based on the equation for t in table 1. Table 10 is applicable for both tables 8 and 9. Moreover, the average and maximum number of hits of the groups are displayed as well as the average number of hits by road class. The second part of table 9 shows the impact of the level of service on the number of hits. A level of service of 0.975 is required to minimize the number of second accidents for interstate subgroup 4. It is noted that the one accident remaining is the result of two accidents reported on the same day.

5. Select a level of service.

   Since the selection of a level of service requires a policy decision, the policy was based on existing practice and contract provisions. The inspection interval required was equal to the existing average inspection interval, but not greater than seven days. The restoration period specified in the contract for guardrail maintenance was five working days which was expanded to seven calendar days. The long reaction times are the primary factor in the level of service, and they are contingent on the requirement that there be 200 linear feet of guardrail needing repair before the repair crews are committed to the repair work. This requirement makes the restoration period unpredictable and widely variable from county to county. The existing levels of service calculated for the field sites and the restoration levels required to achieve a minimum level of service of 0.8 are shown in table 11. The minimum level of service was based on the assumption that it is a practical lower limit of level of confidence in statistics.

Four of the levels of service are below 0.8. In order to reduce the existing restoration intervals to obtain the intervals required for a 0.8 level of service, substantial time reductions are needed.

Obviously, changes in the contract's provisions and their enforcement would be essential to reach the minimum desired level of service, along with possible reduction in inspection intervals.

Table 3. Grouping of Interstate Locaations

ROUTE NO.	LOCATION	MILE POST	NO. ACCIDENTS
395 Signs,2	WASH. BLVD	2.75	6.00
395 Hardware,1	RAMP TO RT 236	2.61	5.00
395 Hardware,2	RAMP TO RT 120	1.45	4.00
395 Signs,2	RT 110 EXIT	3.85	4.00
395 Hardware,2	RT 110	3.65	3.00
395 Hardware,2	ARLINGTON RIDGE RAMP	3.49	3.00
395 Hardware,1	RAMP TO EDSALL RD	0.98	3.00
395 Signs,2	RAMP TO RT 27	2.38	3.00
395 Signs,2	BOUNDARY CHANNEL DR	4.18	3.00
395 Hardware,2	RAMP TO RT 120	1.13	2.00
395 Hardware,2	1 MI N OF RT 120	2.32	2.00
395 Hardware,2	NEAR BOUNDARY CHANNEL	4.19	2.00
395 Hardware,2	0.5 MI N OF RT 120	1.82	2.00
395 Hardware,1	RAMP TO DUKE ST	2.80	2.00
395 Hardware,1	0.75 MI N OF DUKE ST	3.50	2.00
395 Hardware,1	1 MI N OF EDSALL	2.11	2.00
395 Hardware,1	SEMINARY RD	4.25	2.00
395 Hardware,1	NEAR DUKE ST	3.00	2.00
395 Signs,2	RAMP FR/TO WASH. BLVD	3.52	2.00
395 Signs,2	SHIRL. EXIT	0.90	2.00
395 Signs,1	SEMINARY RD	4.13	2.00
395 Signs,1	RT 7	5.01	2.00
64	E OF I 664	40.30	2.00
64	RAMP TO I 664	39.96	2.00
395 Hardware,2	0.5 MI S OF RT 120	0.92	1.00
395 Hardware,2	RAMP TO WASH BLVD SB	3.52	1.00
395 Hardware,2	.25 MI S OF WASH BLVD	2.50	1.00
395 Hardware,2	RAMP TO G W PARKWAY	4.37	1.00
395 Hardware,2	500 FT N OF RT 7	0.06	1.00
395 Hardware,2	RAMP TO SHIRLINGTON	0.53	1.00
395 Hardware,2	RAMP TO WASH BLVD	2.38	1.00
395 Hardware,1	0.1 MI S OF EDSALL	1.01	1.00
395 Hardware,1	0.5 MI N OF EDSALL	1.51	1.00
395 Hardware,1	RAMP TO I 495	0.33	1.00
395 Hardware,1	0.1 MI N OF EDSALL	1.21	1.00
395 Hardware,1	.75 MI S OF RT 236	2.00	1.00
395 Hardware,1	I 495	0.15	1.00
395 Signs,2	RIDGE RD	2.49	1.00
395 Signs,2	RAMP TO GLEBE RD	1.45	1.00
395 Signs,2	RAMP TO RT 7	0.13	1.00
395 Signs,1	S OF RT 7	5.16	1.00
395 Signs,1	RT 236 EXIT	2.80	1.00
395 Signs,1	EDSALL RD	1.11	1.00
395 Signs,1	RT 236 RAMP	2.61	1.00
395 Signs,1	TO EXPRESS LANE	2.08	1.00
395 Signs,1	RT 648 RAMP	0.98	1.00
64	RAMP TO I 664	40.54	1.00
64	0.25 MI W OF LASALLE	40.30	1.00
64	0.2 MI W OF I 664	40.11	1.00

Table 9. Grouping of Primary Route Locations

ROUTE NO.	LOCATION	MILE POST	NO. ACCIDENTS
50 Signs	MANCHESTER	5.06	18.00
50 Signs	WASHINGTON BLVD	2.23	13.00
50 Signs	PARK ST	4.07	11.00
50 Signs	FILMORE ST	2.57	5.00
150	FALLING CREEK RD	3.55	5.00
50 Signs	FT MYERS	1.82	4.00
50 Signs	GEORGE MASON	3.55	4.00
150	POCOSHOCK CREEK	4.15	4.00
50 Signs	W OF WASH BLVD	2.40	3.00
50 Signs	LEXINGTON ST	4.71	3.00
50 Signs	PERSHING DR	3.73	3.00
150	WALMSLEY	4.52	3.00
50 Hardware	500 FT E OF WASH BLVD	2.13	2.00
50 Hardware	WASHINGTON BLVD	2.23	2.00
50 Hardware	FT MYER DR	1.12	2.00
50 Signs	D.C. CITY LIMITS	0.22	2.00
50 Signs	COURT HOUSE RD	1.42	2.00
150	NEAR RAILROAD BRIDGE	0.70	2.00
150	NEAR WALMSLEY	4.38	2.00
150	NEAR RT 10	2.84	2.00
150	RT 360	5.43	2.00
50 Hardware	RAMP TO MEADE	0.63	1.00
50 Hardware	G W PKWY	0.23	1.00
50 Signs	W OF 10TH ST	1.58	1.00
150	0.15 N OF BELMONT	4.05	1.00
150	0.8 IM S OF RT 360	4.65	1.00
150	.12 MI E OF RT 10	2.74	1.00
150	1500 FT N OF WALMSLEY	4.86	1.00
150	1800 FT S OF RT 360	5.11	1.00
150	0.4 MI N OF RT 10	3.30	1.00

Table 10

Range of Inspection and Restoration Intervals

Group No.	Hits Per Year	Expected Number of Days Between Successive Hits for Selected Probability Levels					
		0.7	0.8	0.9	0.95	0.975	0.99
1	14.0	9.3	5.8	2.7	1.3	0.7	0.3
2	4.4	29.6	18.5	8.7	4.3	2.1	0.8
3	3.0	43.4	27.1	12.8	6.2	3.1	1.2
4	2.0	65.1	40.7	19.2	9.4	4.6	1.8
5	1.0	130.2	81.4	38.5	18.7	9.2	3.7
6	5.0	26.0	16.3	7.7	3.7	1.8	0.7
2 max.	6.0	21.7	13.6	6.4	3.1	1.5	0.6
1 max.	18.0	7.2	4.5	2.13	1.0	0.5	0.2

	Actual	Number of Second Hits					
Interstate							
Subgroups 6	1	1	1	0	0	0	0
3	1	1	1	0	0	0	0
4	3	2	2	2	2	1	1
5	0	0	0	0	0	0	0
Total	5	4	4	2	2	1	1
Primary							
Subgroups 2	6	3	2	1	0	0	0
3	1	0	0	0	0	0	0
4	4	0	0	0	0	0	0
5	0	0	0	0	0	0	0
Total	11	3	2	1	0	0	0

Table 11

Existing Level of Service and Desired Level of Service

	Existing			Desired	
	Hits per year	Restoration Interval, days	Level of Service	Restoration Interval, days (from Table 1)	Level of Service
I-395, hardware, 1	5	7 + 26 = 33	.64	16.3	.80
I-395, hardware, 2	3	7 + 33 = 40	.72	27.1	.80
I-395, signs	6	3	.95	3	.95
I-64	4	5 + 121 = 126	.25	20.4	.80
Rt. 50, signs	18	3	.86	3	.86
Rt. 50, hardware	2	3 + 33 = 36	.82	36	.82
Rt. 150	5	4 + 42 = 46	.53	27.1	.80

PROBLEMS WITH THE METHOD

The field evaluation identified several problems with the method.

Overestimate of Second Accidents

The number of second accidents expected was significantly greater than the actual number of second accidents. According to the maintenance supervisors at the study sections, second accidents seldom occur. It is quite common, however, for accidents to occur about 50 to 100 feet from the damaged safety hardware. This problem may be resolved by applying an adjustment factor to reduce the estimate of second accidents, or by basing the expected number of second accidents on the actual experience of second accidents. The value of using an adjustment factor is questionable since it lacks a theoretical basis. This problem is eliminated if the overestimate is perceived as a margin of safety.

The expected number of second accidents based on the procedure is approximately equal to the annual number of accidents. The maximum number of second accidents equals the number of annual accidents minus one. Since accidents are random occurrences, it is not likely that the maximum number of second accidents would occur at all locations, all of the time. This explains why the procedure poorly predicted the actual number of second accidents. It is very important to state in the procedure that the worst conditions are addressed. In this way, the procedure will not be expected to predict actual second accidents.

Definition of a Location

The number of accidents at a location would be significantly reduced by using one-hundredth mile (52.8 ft) as the basic unit of measurement as is done in Virginia rather than one-tenth of a mile (528 ft). This change would also more adequately identify the accidents occurring near the damaged safety hardware. The next step in more specifically defining the location is to consider the direction of travel of the vehicle and the side of the road on which the damaged safety hardware is located. These changes substantially reduced the number of hits per year for each site. Consequently, when the current inspection repair activities are applied to the revised number of accidents, the level of service substantially increases. The existing level of service in table 11 is revised in table 12 for a one-hundredth mile basic unit, direction, and side of road. The level of service increases to greater than 0.7 for all sections compared to three sections with levels of service below 0.7 for one-tenth mile basic unit. Consequently, the method of defining the location significantly affects the results of the procedure. The more well defined the location, the more accurately the potential for a second accident is estimated.

Immediate Versus Scheduled Repairs

In practice, the damage to the highway safety hardware is assessed and is either considered for immediate repair if there is a definite hazard or scheduled for repair if the damage is minor or less of a hazard and the guardrail is functional. The procedure does not take this into consideration. Moreover, severely damaged highway safety hardware is sometimes reported immediately by the police. Consequently, the safety hardware may be repaired before the next inspection. These activities reduce the potential for a second accident occurring. It would be helpful if this issue were taken into consideration in the procedure. An immediate repair may assume a level of service of 0.995.

Need for Traffic Safety Evaluation

It would be helpful if the procedure emphasized the need for traffic safety evaluations at locations with high accident frequencies. Safety improvements may be substantially effective in reducing first accidents as well as second accidents. Although safety improvements are not in the scope of the study, the procedure is remiss in not mentioning the need.

Table 12

Comparison of Level of Service by Location Unit

	Location unit - 1/10 mi.			Location unit = 1/100 mi. by direction by side of road	
	Hits per Year	Restoration Interval	Level of Service	Hits per Year	Service
I-395, hardware 1	5	7 + 26 = 33	.64	3	.76
I-395, hardware 2	3	7 + 33 = 40	.72	3	.72
I-395, signs	6	3	.95	2	.98
I-64	4	5 + 121 = 126	.25	1	.71
Rt. 50, signs	18	3	.86	8	.94
Rt. 50, hardware	2	3 + 33 = 36	.82	1	.91
Rt. 150	5	4 + 42 = 46	.53	1	.88

CONCLUSION

The method described in "A Method for Determining Frequencies to Inspect and Repair Highway Safety Hardware" appears to have a high potential for improving highway safety hardware maintenance practices. Based on the findings of this field evaluation, the method is useful for highway safety hardware maintenance guidelines.

Most maintenance guidelines are determined subjectively. This method provides statistically-based quantitative guidelines by means of which incremental maintenance needs (inspection and restoration intervals) and benefits (reduced number of second accidents) are realized. Moreover, by considering the maximum second accident conditions, the method determines inspection and repair intervals for the worst conditions. A substantial margin of safety is built into the method.

Four minor problems in the method were noted.

1. The number of expected second accidents is not a prediction of the actual number of second accidents; the expected second accidents represent the worst conditions not the actual conditions.

2. The basic unit of one-tenth of a mile is ineffective. A location is effectively specified using one-hundredth mile as a basic unit of measure.

3. The practice of assessing damage for immediate versus scheduled repairs is not addressed.

4. The need for a traffic safety evaluation at high accident locations is not addressed.

One of the most important findings is that the time required for guardrail repair to be performed under contract creates potentially hazardous conditions on Virginia roads. The contract calls for repairs to be made within 5 workdays of notification of a minimum of 200 feet of damaged hardware. At the field sites, the average time from damage report to repair ranges from 26 to 121 days. According to the maintenance supervisors in one county, the major problem is that the contractor does not have the equipment and manpower to perform the work within the contract provisions. Another problem is that new guardrail is sometimes installed under the guardrail repair agreement. This adds additional work to an already overloaded work schedule. Moreover, the time required to accumulate 200 linear feet of damaged guardrail varies considerably from county to county, and probably varies over time. In one county, it takes about 4 months to accumulate 200 linear feet of damaged guardrail, whereas it takes another county only two weeks. Consequently, this stipulation makes the restoration period unpredictable. Resolution of this problem offers the largest possible reduction in the restoration time.

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RECOMMENDATIONS

The results of this study provide support for the following recommendations.

1. The Federal Highway Administration should sponsor minor revisions to the method as noted in this report, and consider supporting the use of the method nationwide.

2. The Virginia Department of Transportation should:

   (a) consider implementing the method for determining inspection and repair frequencies for highway safety hardware,
   (b) consider revising the special provision for maintenance of guardrail and median barrier,
   (c) examine highway safety hardware inspection practices and changes necessary to implement the method,
   (d) improve the cooperation with police departments to facilitate accident reporting of damaged safety hardware, and
   (e) examine the use of the concept of this method for other maintenance activities such as traffic signals.

Recommendations b, c, and d would make implementation of the method more effective. However, each recommendation may be acted on separately.

REFERENCES

1. Virginia Department of Highways and Transportation, "Summary of Accident Data -- 1982" (Richmond: 1983).

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5. Virginia Department of Highways and Transportation, "Special Provision for Replacement of Guardrail and Median Barrier" (Richmond: February 28, 1986).

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APPENDIX

A STEP-BY-STEP METHOD

FROM

A METHOD FOR DETERMINING FREQUENCIES TO INSPECT AND REPAIR HIGHWAY SAFETY HARDWARE

The following steps are suggested for applying this method to the selection of time intervals for inspection or restoration of safety hardware:

Step 1 - Obtain Safety Hardware Accident Data

Usually, the best source of safety hardware accident data will be special studies by the maintenance or traffic engineering divisions in the highway agency. In the absence of such studies, traffic accident records are the next best source of information. If traffic accident records are used, a special file should be created to contain only those accidents involving safety hardware, preferably by type. This file should permit separate summaries and calculations for each geographic unit (e.g., maintenance district or county) for which maintenance and scheduling decisions are made. The agency's program that produces a listing of high accident locations should be used to process the safety hardware accident file to identify annual accident averages and accident rates. Depending on the age of the data and the recent growth of traffic volumes, it may be preferable to adjust the data to reflect the current expected annual accident averages.

Having determined the current average annual number of accidents involving safety hardware by location, the figures should be adjusted to reflect incomplete reporting. This information is not always available and current in every state so it may be necessary to use the best available estimates of local experience or information from another state until better data can be obtained. One state has conducted studies indicating the following approximate proportions of accidents reported:

Type of Accident	Level of Reporting
Fatal	100%
Injury	80%
Property Damage	40%

To demonstrate the planning method, these proportions were used to adjust the accident totals.

Step 2 - Rank the Accident Locations

The safety hardware accident locations should then be sorted in rank order by decreasing frequency of accidents. At minimum, this listing should contain location, road class, and the average annual number of safety hardware accidents, by type if possible. Accident rate and average daily traffic may be included, if desired, but is not necessary if the average annual frequency has been adjusted to current or projected traffic conditions.

Step 3 - Sort and Group Locations

It is preferable to select the least number of inspection and restoration intervals that will adequately represent the range of average annual accidents of the special file. This requires a sorting scheme that will be compatible with available data and with the current bases for highway management decisions. Existing road classification systems, such as functional class, traffic volume groups, and marked route systems, are used to designate organizational responsibilities for design, safety, and maintenance and to reflect the sources and allocations of funds.

Any set of road classifications can be used to sort the safety hardware accident file as convenient to the highway agency. The groupings should reflect opportunities for hardware accidents, i.e., highway design type, hardware type, and traffic volume. Usually, the higher functional classes and traffic volumes require more sophisticated design features, including hardware.

The sorted hardware accident file should be inspected for natural groupings of the annual number of accidents. For example, a group of locations on the Interstate System might contain several locations with average annual accidents in the 6 to 7 per year range and several in the 2 to 3 per year range. This would suggest separating the group into two subgroups. Further inspection should yield a relatively small number (maybe a dozen) of groups of road locations and segments, by road class, for which similar frequencies of annual accidents have been recorded.

Step 4 - Identify the Range of Intervals

The next step is to identify inspection and restoration intervals for the groups of locations and segments. This requires choosing an annual accident frequency to represent each group. These frequencies should be similar within a group so that an average might be used. However, a more conservative approach would suggest using the largest annual accident frequency of each group. This frequency is used with Table 1 (with Table 2 as needed) to identify the range of intervals which can be chosen, corresponding to different probabilities of no accidents within an interval. For example, if the annual accident frequency (hits per year) for a group is 3.4, Table 1 indicates the range of intervals from 24.0 to 0.5 days for probabilities from 0.800 to 0.995. When the range of intervals has been designated for each group of locations, the routine portion of this method has been completed.

Step 5 - Select a Level of Service

The final step requires preparation for and obtaining a policy decision on the level of service, expressed as the desired probability(ies) of completing inspection and restoration before a subsequent accident. A single service level will designate different intervals for hardware types and groups of locations or segments according to the representative accident frequencies observed. The preparations will require calculations or estimates of labor, equipment, and materials that will be needed to implement a set of intervals for two or more service levels. Maps of a district or other geographic unit, with color or other codes to identify the intervals shared by hardware types and groups of locations or road segments, will help to clarify this choice and will facilitate subsequent implementation.

The maximum restoration times for different service levels should be reviewed in terms of the agency's available resources and its inventory of safety hardware. Higher service levels will provide greater protection to the motoring public but at higher costs. Lower levels will afford less protection and may expose the highway agency to accident-related liabilities. This trade-off requires a policy decision about the highest level of service that the agency can afford, considering other responsibilities and priorities.

The risk associated with the selected policy is reflected in the probability level. For example, if a P(0) of 0.95 is selected, there is a 5 percent chance that one or more accidents will occur within the selected restoration time period. If the 0.95 level corresponds to a restoration period of 7 days, then for 100 periods of 7 days (approximately 2 years), the policy would be expected to fail no more than 5 times; that is, 5 second hits on damaged safety devices may occur before the repairs are completed.

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