MICHIGAN DEPARTMENT OF STATE HIGHWAYS

ACCIDENT ANALYSIS AND COST JUSTIFICATION

-LEFT SIDE PENNANT SIGN - US-12 -

Supplementary Report
To
STUDY OF NO-PASSING ZONE SIGNING

By

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Conducted By

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I. INTRODUCTION

This report is an extension of the Michigan Department of State Highways "Study of No-Passing Zone Signing" dated May 1965. For physical description, visibility characteristics and drivers' reaction to the pennant sign, one should refer to the original study.*

A cost-effectiveness analysis technique has been applied to the accident data to show when installation of the pennant "No-Passing Zone" sign along a continuous route may be cost-justified as a safety improvement.

Where the words "relevant accidents" are used in this report, they are defined as accidents occurring within a no-passing zone or within the adjacent 500 feet at either end of a no-passing zone.

The cost-effectiveness technique evaluation is restricted to passing accidents in areas within no-passing zones or within the 500 feet approaches to the no-passing zones.

II. TEST SITE

The site selected for this evaluation was Michigan trunkline US-12, a two-lane, two-way roadway extending approximately 170 miles across southern Michigan from Berrien County to Washtenaw County inclusive.

*For additional information, refer to "The Researchable Aspects of No-Passing Zone Signing and Marking", Don C. Kelly and John D. Sidnell, Dept. of Civil Engineering, Univ. of Kentucky, Lexington, Kentucky, 1967.

During July and August, 1964, 316 pennants were installed at the 158 no-passing zones through the study site.

ADT's varied widely between control sections along this route. Taking a weighted average, using the lengths of the control sections as weights, the after period showed a slight increase in traffic counts. (See Table 3. pg. 13)

III. PROCEDURES

Data Collection

Accident reports were provided by the State Police or local authority through the Safety and Surveillance Section of the Michigan Department of State Highways. The location of the reported accidents was manually correlated with the no-passing zone locations.

The ADT's listed are the estimates from Traffic Survey and Transportation Analysis Section's records.

The accidents and ADT's for one year before and one year after the installation are displayed in Tables 3 through 6 of Appendix 3.

Cost-Effectiveness Technique

For cost analysis, it was decided the statistical model should be restricted to passing accidents. These accidents were considered as being generated by a Poisson Probability Distribution function of unknown mean. It was further decided the total number of passing accidents to be observed should be fixed at 30 rather than the alternative of fixing the length of time for observing.*

To reach these 30 passing accidents necessitated considering 398 days before and 398 days after sign installation. A description of counting procedure is given in Appendix 2 pg. 9.

The cost of an accident involving injury to one or more persons was fixed at $1800. The cost of an accident involving property damage only was fixed at $400. Fatalities were not considered. No justification of these figures is given in this report; however, it was intended that these figures be chosen sufficiently conservative so as to avoid detracting from the conclusions of this report.

IV. CONCLUSIONS

Comparing the accident rate indicated there was a relative improvement in the relevant accident rate when compared with the rate of all accidents on the highways. There was an actual decrease in the number of passing accidents in the no-passing zones. (See Appendix 3, Tables 5 & 6)

*Advantages of conditioning the experiment on a fixed number of observed accidents are discussed in D. Blackwell and M. A. Gershick, Theory of Games and Statistical Decisions, John Wiley and Sons, New York, 1954.

The analysis based on 17 accidents before and 13 accidents after showed one may anticipate fewer passing accidents per year in the no-passing zones where the pennant is installed than where the pennant is not installed. The mean decrease realized in the number of passing accidents after the installation of the pennant sign would be 28%. (See Appendix 2, Table 1).

The cost-effectiveness conclusions are presented in Graph 1, Appendix 1: Mean Annual Passing Accidents vs. Total Installation Cost in Thousands of Dollars.

The graph shows the mean number of accidents per year required where the pennant is not installed to justify the installation cost of a project. A project was defined to be sufficiently large so that the driver is able to educate himself as to the meaning of the pennants.

Technical aspects of the development of the graph are given in Appendix 2. With some simplification being employed, the graph answers the question: How much money does this annual 28% reduction in passing accidents represent? The answer naturally depends on the present number of passing accidents being experienced as the graph shows.

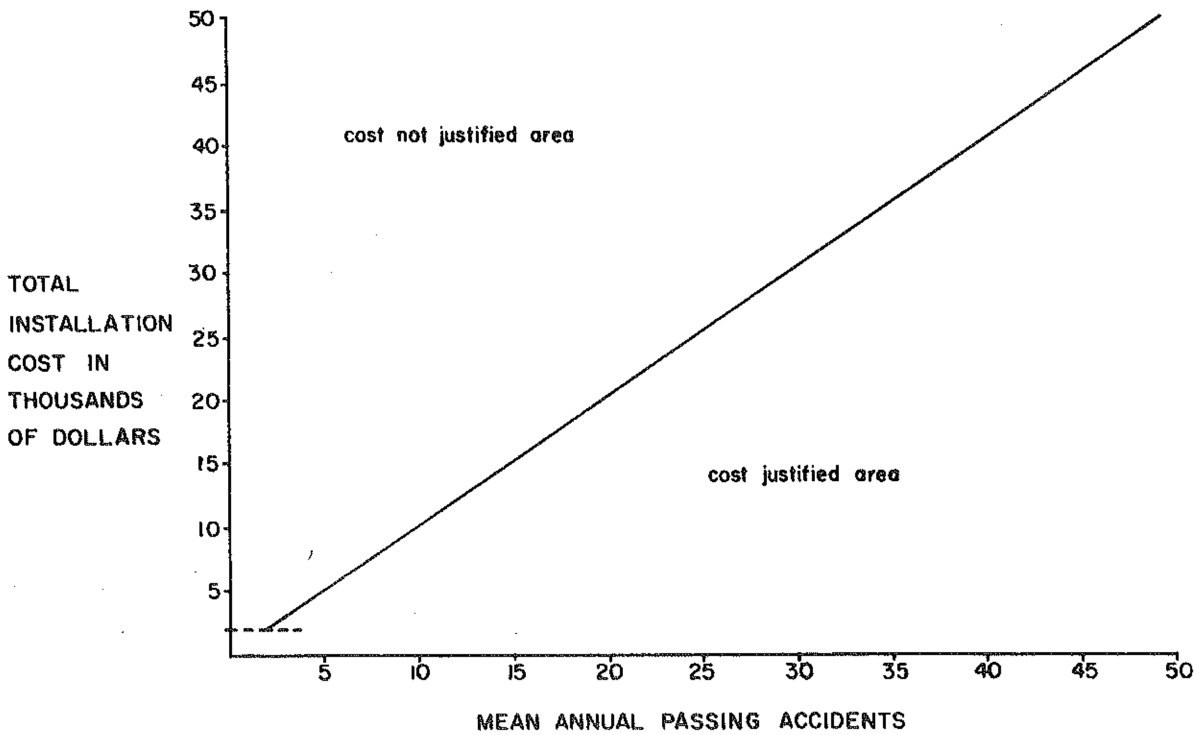
The purpose of the graph is to aid management in the selection of further sites where the pennant should be installed, and, indirectly, to encourage the acceptance of this sign as a standard.

V. RECOMMENDATIONS

(1) Based on this report, it is recommended that the Michigan Department of State Highways continue its efforts to establish the pennant sign as a national standard or as an optional signing approach.

(2) It is further recommended that efforts be made in accident analysis toward identifying the number of passing accidents occurring within no-passing zones throughout the state. This report again indicates the importance of being able to identify road characteristics and types of accidents.

APPENDIX 1



Graph 1.

To use this graph, take the cost of installation and the number of passing accidents observed during one year where the sign is to be installed, and plot this point. If the point lies above and to the left of the line on the graph, the installation is not cost-justified. The vertical height from the plotted line represents the five-year loss involved if the sign is installed.

If the point lies below and to the right of the line on the graph, the installation is cost-justified. The vertical distance from the plotted line represents the five-year return.

The graph is based on the total cost of the installation, and, therefore, may be used for any price per pennant.

For US-12, 15 passing accidents were observed the year before the pennant was installed. The installation estimated cost was $11,060. If one enters the graph with the 15 accidents, one sees that a cost of $15,370 would be justified. Thus, having observed the 15 accidents, pennant installation would have been recommended.

Examples of Use of Graph:

Example 1: A trunkline has 80 passing zones on a 70-mile distance:

Cost of installation

	80	zones
	2	pennants/zone
	160	pennants
$	40	cost per installed pennant
$	6,400	

Going into the graph with the $6,400, it is seen that an annual mean of 7 or more passing accidents in these 80 zones during preceding years would justify the installation.

Example 2: On the 55 passing zones on a route, 18 passing accidents occurred during the preceding year.

Going into the graph, using the 18 accidents and considering the cost of the 110 pennant signs, it follows that $13,900 would be the expected reduction in expected loss if the pennant was installed inasmuch as an expenditure of $18,300 would be justified and the cost of installing the signs is $4,400.

APPENDIX 2

Cost-Effectiveness Technique Analysis

The accidents were considered as being generated by a Poisson process.

$$\text{Probability of K accidents} = \frac{R^k e^{-R}}{k!}$$

where K is the number of accidents observed in one year

R is the annual mean number of accidents

Let R_1 be the mean for the year preceding the pennant sign installation.

Let R_2 be the mean for the year following.

For mathematical convenience the ratio

$$p = \frac{R_1}{R_1 + R_2} \qquad (1)$$

was considered. Thus $p > 1/2$ indicates the old mean is greater than the new, $p = 1/2$ no change, and $p < 1/2$ the new mean is higher.

If the test is then considered as a binomial experiment of 30 trials with trials resulting in an accident either before or after the installation, p is then the probability that a trial will result in observing an accident from the year before.

$(1-p)$ or $\frac{R_2}{R_1 + R_2}$ is the probability a trial will result in an accident from the year after.

Thus, for our sample 17 before, 13 after*

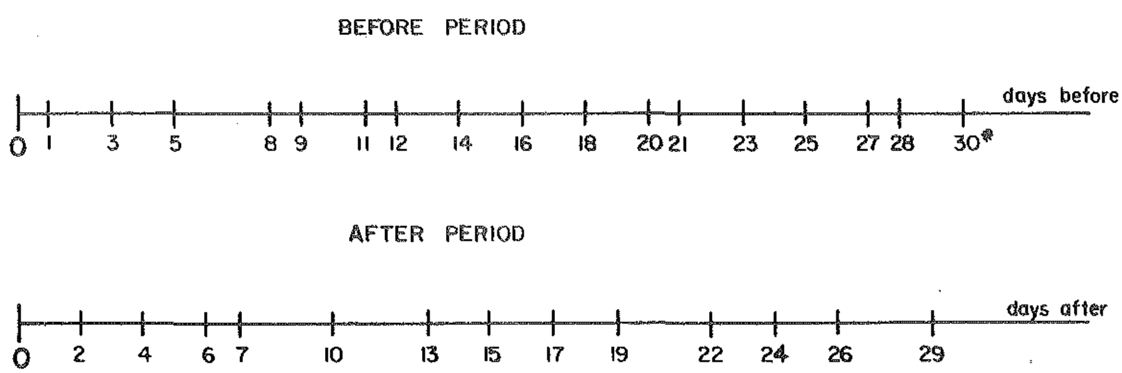
$$\binom{30}{17} p^{17} \quad (1-p)^{13} \qquad (2)$$

is the probability of having observed the sample.

An estimate of p will provide an estimate of the project percent improvement in the accident rate after the installation.

In order to use the information concerning the safety features of the pennant contained in the earlier study for this estimation, and to introduce a cost structure for the cost-effectiveness technique analysis, Bayes procedures were applied.

*The accident count was considered as beginning on the day of the pennant installation. The before and after time periods were treated as simultaneous occurrences. The count was terminated when 30 accidents were obtained. A graphic representation is given below. Each number 1 to 30 represents an accident.



A Beta Distribution $f(p;a,b)$ was selected to assign a priori probabilities to the possible values of p where

$$f(p;a,b) = \frac{\Gamma(a+b)}{\Gamma(a)\ \Gamma(b)} p^{(a-1)} (1-p)^{(b-1)}$$

A suitable choice of a and b usually provides sufficient flexibility to meet the engineer's needs in assigning a given probability to any small set of subintervals of (0,1).

The particular parameters selected for the Beta Distribution were a = 15, b = 10. These parameters were selected because of the following consideration:

(a) The pennant sign installation was unlikely to raise the accident rate. Under the parameters chosen, the probability of the situation worsening was .15.

(b) There was almost no probability that the new accident rate would be decreased by more than 67%. This reflects the opinion that during times of good visibility, the present standard markings are effective. Under the parameter chosen, the probability of a greater improvement than 67% is .0035.

(c) The most probable improvement would be in the neighborhood of a 33% decrease. This reflects the fact that a high percent of the accidents occur during the early phases of the passing maneuver. This is the time when a driver's view of the standard "Do Not Pass" sign is most likely obscured and the pennant is most apparent.

The posterior probability that p is between any two values, $(c,d) \subset (0,1)$ given 17 accidents before, 13 accidents after, is

$$P(c<p<d \mid 17 \text{ before, } 13 \text{ after}) = \tag{3}$$

$$\frac{\int_c^d \binom{30}{17} p^{17} (1-p)^{13} f(p;a,b) \, d(p)}{\int_0^1 f(p;a+17, b+13) \, d(p)}$$

$$= \int_c^d f(p;a+17, b+13) \, d(p)$$

This integral is evaluated in Table 1 for a = 15, b = 10.

The calculation of the expected cost of a passing accident in a no-passing zone is shown in Table 2. The cost of a fatal accident was omitted.

The estimation of 40% of passing accidents involving injury is based on the data contained in this report. (Table 6)

The accident cost reduction is then based on p(1) considering the rate as known. The expected reduction in accident loss is then the integral of the product of the posterior probability (3) and the loss function (Graph 2).
This integral was evaluated by standard computer techniques.

The cost-effectiveness, (Graph 1), compares the mean annual accidents with the installation cost of the pennant.

In making the calculations for this graph, the payments were in five annual installments with a 7% interest rate. Five years is the expected life of the pennant. No maintenance cost was included in the construction of this graph.

Table 1

Probability Distributions of Percent of Rate Change

	$R_1 < R_2$	$R_1 < \frac{3}{2} R_2$	$R_1 < 3R_2$	Mean Value
A priori	.15	$\backsim$.5	.995	$R_2 = .66R_1$
Posterior	.11	.602	.996	$R_2 = .72R_1$

Graph 2

Accident Cost Reduction Function

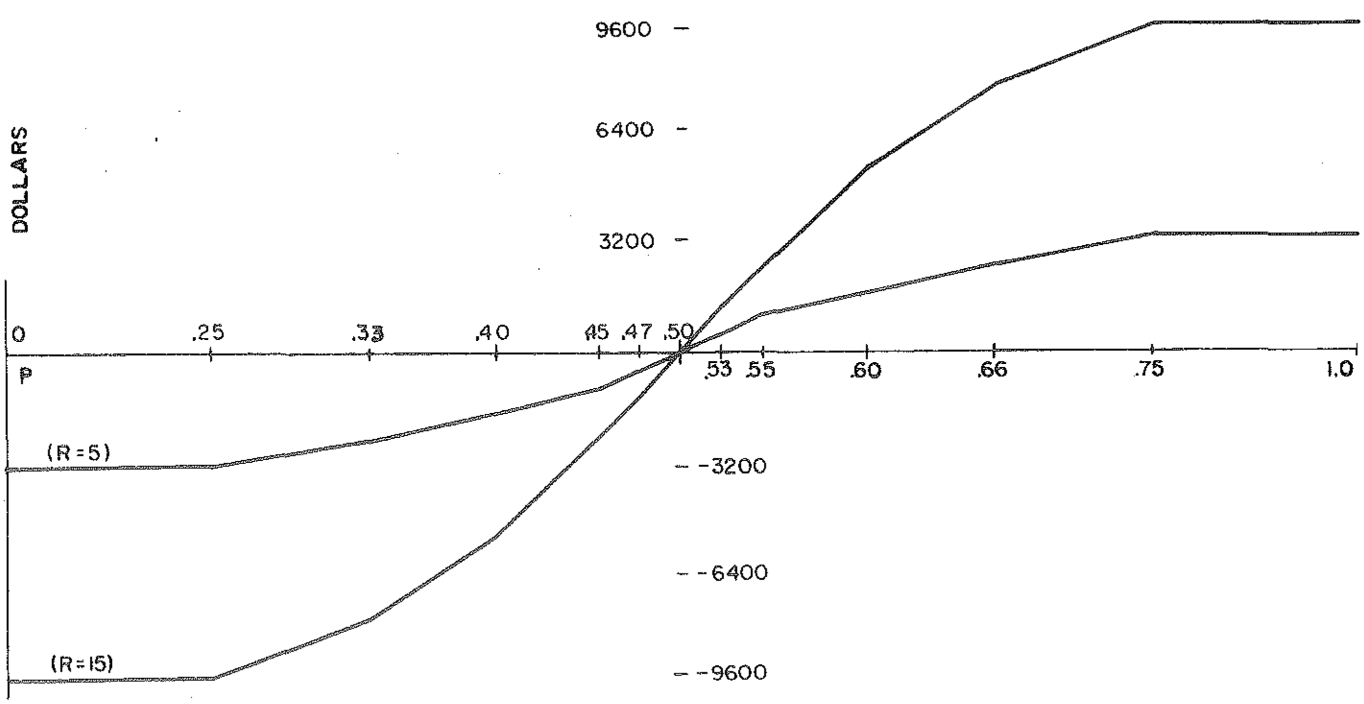


Table 2

Loss Involved In Accidents

	Loss		Probability		
Personal Injury	$1800	x	2/5	=	$720
Property Damage	400	x	3/5	=	240
Conditional Expected Loss					$960

APPENDIX 3

One year before and one year after data and observations

Table 3
US-12 Control Sections
Volume and Sign Installation Data

Control Section	"Before" ADT	"After" ADT	ADT'S 1963	1964	1965	New Signs Installed
11021	4200	3700	4800	3800	3715	7-29-64
14041	2600	2700	2600	2600	2833	"
14042	2800	2900	2900	2800	2871	"
78021	3500	2900	3600	3400	2550	"
78022	4000	4100	4100	4000	4192	"
12021	3200	3200	3400	3100	3345	"
12022	6100	5800	6300	5900	5835	"
30061	4100	4000	4500	3900	3966	8-31-64
30062	3400	3100	4100	3000	3184	"
46101	4000	4200	4500	3700	4453	8-24-64
81031	5800	6500	5700	5900	6785	8-11-64
81032	9000	12200	7800	9800	13828	"
Weighted Average	4200	4300				

Table 4

US-12 No-Passing Zone Accident Rates

By Control Section

Control Section	No-Passing Zone Length * (Miles)	One Year Before Pennant Signs: ADT	Yearly Vehicle-Miles(000)	Number of Accidents	Accident Rate **	One Year After Pennant Signs: ADT	Yearly Vehicle-Miles	Number of Accidents	Accident Rate **
11021	8.450	4200	12,954	17	131	3700	11,412	27	236
14041	8.807	2600	8,358	20	239	2700	8,679	14	161
14042	1.578	2800	1,613	7	434	2900	1,670	2	120
78021	0.296	3500	378	1	265	2900	313	1	319
78022	5.051	4000	7,374	27	367	4100	7,559	25	331
12021	0.694	3200	811	3	370	3200	811	2	247
12022	2.278	6100	5,072	12	237	5800	4,823	16	332
30061	4.954	4100	7,414	6	81	4000	7,233	7	97
30062	13.750	3400	17,064	41	240	3100	15,558	45	289
46101	18.890	4000	27,579	66	239	4200	28,958	70	241
81031	11.982	5800	25,366	46	181	6500	28,427	61	215
81032	1.025	9000	3,367	8	237	12200	4.564	14	307
	77.755			254				284	

* Including 500' at each end

** Per 100 million vehicle miles

Table 5

Comparison of Accident Rates*
Before and After by Control Sections

Control Section	Before		After		Lengths (Miles)	
	Whole Sections	No-Passing Zones**	Whole Section	No-Passing Zones**	Control Section	No-Passing Zones, Including 500' at Each End
11021	177	131	188	236	24.996	8.450
14041	264	239	242	161	16.011	8.807
14042	315	434	325	120	10.572	1.578
78021	234	265	381	319	5.146	0.296
78022	331	367	376	331	19.912	5.051
12021	213	370	286	247	17.837	0.694
12022	216	237	258	332	9.259	2.278
30061	146	81	177	97	8.860	4.954
30062	196	240	274	289	16.960	13.750
46101	235	239	294	241	21.690	18.890
81031	211	181	248	215	17.152	11.982
81032	789	237	615	307	7.847	1.025
Total					176.242	77.755

*Per 100 million vehicle-miles

**Including 500' at each end.

Table 6

Summary Of
Accidents Before and After Pennant Signs
on US-12 No Passing Zones

(One-Year Periods)

Description	Before	After
1. All accidents on the no passing zones[1]	254	284
a. All injury-accidents	101	112
b. All property-damage accidents	153	172
2. All passing-accidents on US-12[2]	79	89
a. Starting to pass	31	14
b. In process of passing	30	69
c. Completing passing	12	1
d. Avoiding oncoming vehicle	6	5
e. Involving injury	23	27
f. Involving property damage only	56	62
g. Involving head-on collision	2	4
h. In daylight	49	60
i. In dark	30	29
j. Fatal	0	2
3. Passing-accidents on no-passing zones[3]	15	12
a. Starting to pass	6*	0
b. In process of passing	6	12
c. Completing passing	2	0
d. Avoiding oncoming vehicle	1	0
e. Involving injury	5	6
f. Involving property damage only	10	6
g. Involving head-on collision	1	2
h. In daylight	8	8
i. In dark	7	4
j. Fatal	0	0

* - 4 in daylight + 2 in dark

Remarks:

1. The zones for item 1 include additional 500 feet at either end of no-passing zones.

2. In item 2 are all the accidents on the whole length of US-12.

3. In item 3 are accidents involving passing maneuvers on no-passing zones and on the approaches before such zones, within a distance of 500 feet.

Observations

1. Accident rate on the whole of US-12 increased 15.2% during the one-year "after" period, while accident rate on the no-passing zones (including 500' at each end) increased only 10.4%.

2. All accident types on the no-passing zones increased by 11.8%, and passing-accidents on all of US-12 increased similarly by 12.6%. However, the passing-accidents on the no-passing zones decreased from 15 to 12 accidents.

3. Passing-accidents in daylight on the whole road increased by 22.4%, whereas those on the no-passing zones remained the same. Passing-accidents in the dark on the whole road decreased by only 3.3%, but those on the zones decreased from 7 to 4 accidents.

4. On the whole road, there were no fatal passing-accidents during the "before" period, and two during the "after" period. On the no-passing zones, there were no fatals at any time.

APPENDIX 4

Discussion of Technique

A discussion of the selection of the technique presented in this paper is perhaps warranted. If the distinction between an empirical accident rate and a theoretical accident rate (the parameter of a poisson distributor generating the accidents) is made, one is not going to know, with certainty, the theoretical accident rate from observing the accidents which occur over a reasonable length of time. However, a large number of accidents would seem to imply a high rate, and a small number of accidents would seem to imply a low rate.

In safety problems involving before and after studies, one often simplifies the problem of estimating the rate by assuming a test of hypotheses structure for the problem. Using this assumption the possible conditions of the accident rate are placed in two states:

A. The accident rate is lower after the change.

B. The accident rate is the same or higher after the change.

One then observes the sample of before and after accidents and decides between two actions:

A. Act as though the accident rate is lower after the change.

B. Act as though the accident rate is the same or higher after the change.

One intuitively would choose Act A if the number of accidents after the change was lower than the number of accidents before. One would choose B otherwise. (See page 23)

If one chooses Act A when State A exists, or Act B when State B exists, the correct decision is made.

The problem comes when someone implies the improvement or deterioration observed is due to chance and not to a change in the theoretical accident rate.

He implies that one chose Act A when State B (a deterioration) was actually true or one chose Act B when State A (an improvement) was true. The implication may well be plausible, and in many cases, highly probable.

To meet this objection:

One may choose Act A only if the number of accidents observed after is much lower than the number of accidents observed before. One is then unlikely to choose Act A when B is true

Or

One may choose Act B only if the number of accidents observed after is much higher than the number of accidents observed before. In this case, one is unlikely to choose Act B when A is true.

Careful reading of the above two choices indicates that protection against one error comes only at the "price" of an increase in the chance of the error.*

*This statement ignores the possibility of controlling both errors by choosing the sample size sufficiently large. This is justified since in before and after accident studies, the sample size cannot be made arbitrarily large.

Reason would, at this point, look at something outside the artificial structure imposed on the problem, (i.e. "Test of Hypotheses") to determine the chance of error each act should have associated with it. Unfortunately, convenience, the existence of a large class of experiments where it was justified, and a large group of semi-skilled practitioners, lead to further extension of the artificial structure to include always testing one of the hypothesis with an .05 or less chance of error.

An example is perhaps the best way to point out the folly of such an approach when the data is necessarily limited.

An intersection has 15 accidents one year before the length of yellow light is adjusted.

EXAMPLE: Assume the true rates (unknown in reality) were 15 before and is now 10.

Using 0.05 level of test, for 8 accidents or more occurring after, we would conclude there was no improvement. Yet, knowing the rate is 10 now, we will observe 8 or more accidents with probability 0.67. Therefore, a reduction as large as 1/3 will most likely be missed. The conclusion (2/3 of the time) would be that changing the yellow length was ineffective!

If one chooses reason, then he goes outside the problem to determine what action should be taken.

One could hope to balance the probability of either error against some subjective, moral or financial value of the error.

In any event, the testing of hypothesis structure will lose much of its simplicity. Furthermore, the values will be continuously debated.

Having lost its simplicity, there may be little to recommend the test of hypotheses structure.

Bayes Procedure offers an alternative decision procedure. It does not offer any simpliciation, but is able to use the subjective and fiscal values as an integrated part of the analysis. Its basic components are:

1. A loss function in either dollars or utility
2. A subjective probability assigned by a knowledgeable person to the parameter to be evaluated (a priori distribution)
3. The sample.

The analysis is carried out by calculating the a posteriori distribution, integrating the loss function with respect to the a posteriori and taking the act which has the lowest expected loss.

Bayes Procedures were used in the study. The loss function is in dollars.

Graph 1 on Page 12 shows the Accident Cost Reduction Function when the accident per year before the pennant is 5 and 15. The loss function is the Accident Cost Reduction Function minus the annual installment paid to defer the cost of installation.

In Table 1, a few key values of the a priori distribution are shown. The probability density itself is

$$f(p,15,10) = \frac{24!}{14!\ 9!} p^{14}(1-p)^{9}$$

The sample consisted of 17 accidents before and 13 after.

In Table 1, a few key values of the a posteriori distribution are shown. The distribution is given by (3) Page 11.

The graph on Page 6 is not part of the analysis, but makes it easy to apply.

TEST OF HYPOTHESES

State / Act	A *	B *
A *	Act as though State A exists when State A does exist Correct Decision	Act as though State A exists when State B exists Incorrect Decision
B *	Act as though State B exists when State A exists Incorrect Decision	Act as though State B exists when State B does exist Correct Decision

A Decision Procedure:

Let n = number of accidents occurring one year before.

Let n-c = number of accidents occurring one year after.

Choose a number d such that if the accident rate remains the same, the probability that c is greater than d is known. Then, if c is greater than d, choose Act A. The probability of being wrong is the known probability above.

If c is less than d, choose Act B. Now the probability of error should, at least, be considered. Often it is not.

*States and Acts A & B are defined on Pg.18 of this appendix.