

Abridgment

Benefit-Cost Analysis of Advance Treatment for No-Passing Zones

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It was the objective of a recent Federal Highway Administration (FHWA) research project (1) to develop improved criteria and guidelines for establishing passing and no-passing zones, regulatory traffic control devices, and traffic regulations, enforcement methods, and legal requirements that can be uniformly applied throughout the nation for the safety and benefit of all drivers. Alternative methods of establishing and designating passing and no-passing zones were developed to enhance current practice to supply the safety needs. The suggested system was selected because it exhibited the greatest feasibility on the basis of driver understanding, continuity of accepted type of demarcation (longitudinal line adjacent to roadway centerline), satisfaction of the driver's visual information needs, and practicality of installation and maintenance with existing mechanized striping equipment. It consisted of a dotted yellow line adjacent to the roadway centerline throughout the downstream end of the passing zone in conjunction with the standard NO PASSING ZONE pennant sign at the beginning of the no-passing zone's solid yellow barrier stripe.

The details of criteria development, driver understanding studies, and research methodology are included in the final report (1) and are not discussed here, but the salient research results are summarized below:

1. To avoid ambiguity in definitive terminology relating to the passing maneuver, the distance elements involved in the maneuver were defined as illustrated in Figure 1.

2. Minimum passing sight distance ($2/3d_2 + d_3 + d_4$) is defined as the sight distance at which a passing driver at the critical position (passing and passed vehicles abreast) must be able to perceive an opposing vehicle to permit safe completion of the maneuver.

3. A concept of advance marking treatment preceding a no-passing zone demarcation system with a NO PASSING ZONE pennant at the beginning of the solid yellow no-passing-zone line was suggested as a system of traffic control devices that would provide the needed driver information to designate that the passing zone will soon end and that a no-passing zone will be reached.

4. Establishment of a no-passing-zone system should be predicated on minimum passing sight distance for a specified operating speed. The advance marking treatment begins at the point at which sight distance first becomes less than the specified minimum passing sight distance and continues for a distance equal to the pass-completion distance for the specified operating speed; the no-passing zone begins at the downstream end of the advance marking treatment and continues until the minimum passing sight distance again becomes available.

PURPOSE OF THE ECONOMIC ANALYSIS

Traditionally, one of the primary considerations in evaluating a proposed change in concept or practice involves the question, What benefits can be expected from the change? Administrators in the highway pro-

cession are constantly forced to apportion already scarce funds to those areas in which they believe the greatest return will be achieved.

The concept of advance notification is a philosophy generally regarded among traffic engineers as being highly desirable in eliciting proper driver response and, therefore, as contributing noticeably to highway safety. The need for advance warning of a no-passing zone is evidenced by the rapidly spreading adoption of the NO PASSING ZONE pennant sign, the primary approved traffic control device for this purpose. In many cases, the administrative decision to adopt the concept of advance warning for the no-passing zone appears not to have been made on the basis of a detailed benefit-cost analysis but rather as the result of the conviction that driver conditioning to potential hazard is in itself beneficial and the cost of implementing such a system will be offset by improved operations and safety and reduced potential for litigation, although these elements may not have been quantified precisely.

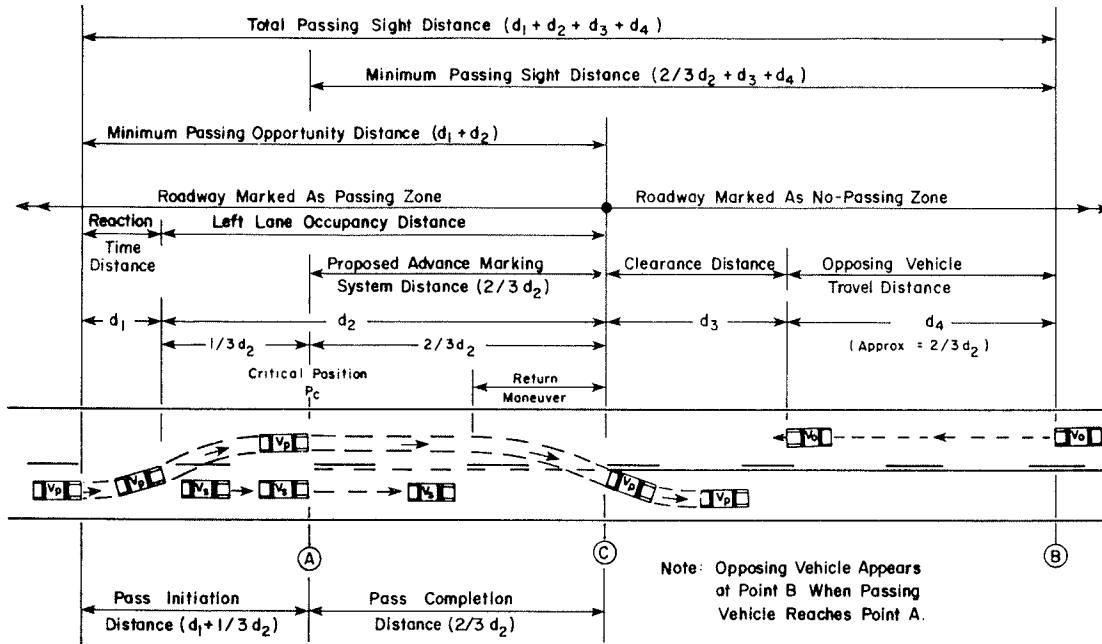
The concepts developed in the research regarding criteria, application, and design of the traffic control devices by which no-passing zones should be established and designated (1) were critically reviewed by 36 traffic engineers in various parts of the country and by a group of members of the National Advisory Committee on Uniform Traffic Control Devices and FHWA in a two-day workshop. In general, the concepts remained unchallenged; the primary concern expressed was that there was a definite need to evaluate the benefits that could reasonably be expected from implementation of the proposed treatments for no-passing zones. This would provide a framework for basing a decision to evaluate, in actual operation, a concept that theoretically appeared sound and reasonable. In response to this rather unanimous expression of opinion, an economic analysis was conducted to predict the expected benefit-cost ratio of application of the advance-warning no-passing-zone treatment proposed in the research effort. This abridged paper presents the results of the economic analysis.

General Approach

The intent during the economic analysis was to be conservative, so that the resulting benefit-cost ratio would represent a very conservative estimate of the relative value of the system. In all probability, the benefits would be substantially greater. To ensure conservatism, several assumptions were made: (a) relatively short sign life was assumed, (b) only those drivers who "clip" the no-passing zone (complete the pass beyond the start of the solid yellow line) were assumed to benefit from the advance treatment, and (c) an interest rate on the high side was assumed.

The approach adopted to compare expected benefits with expected costs on a nationwide basis included estimating the (a) costs of proposed no-passing-zone advance treatment nationwide, (b) number of no-passing zones nationwide, (c) number of passing maneuvers executed annually on two-lane highways nationwide, (d) number of passing maneuvers that involve "clipping", (e)

Figure 1. Distance elements and terminology to define passing design and operations.



number of accidents that involve sight-restricted passing maneuvers, (f) accident reduction due to application of advance treatment, (g) number of lives saved, (h) reduction in injury and property-damage-only (PDO) accidents, and (i) dollar savings of advance treatment, as well as (j) determining the expected benefit-cost ratio.

These tasks were accomplished by using a combination of state-supplied information, previous research regarding passing operations (2), accident statistics from several state studies of advance treatment and from national statistics, and field measurements on the passing maneuver by state agencies. National Highway Traffic Safety Administration (NHTSA) cost values were used in computing benefit-cost ratios.

Estimation of Cost Elements

Expansion Factor for Cost Data

A survey of the states regarding the cost of signing and marking operations was coordinated in 1974 by FHWA, and the results were made available for this research study. Since costs have risen appreciably, the 1974 costs were converted to equivalent 1978 costs by using three independent scaling approaches: the construction-cost-index ratio (3), the consumer-price-index ratio (4), and the bid-price trend on federally aided highway contracts (5). The three approaches indicated 25-35 percent increases in costs from 1974 to 1978. A midpoint value of 30 percent was selected, and the 1978 costs were estimated by applying a factor of 1.30 to the 1974 average costs.

Estimation of Proposed No-Passing-Zone Treatment Costs

The cost of the proposed no-passing-zone treatment is based on (a) sign life of seven years, (b) marking life of eight months, (c) interest rate of 10 percent, (d) marking cost of 8.2 cents/m (2.5 cents/ft), (e) advance treatment of 168 m (550 ft) [88.5 km/h (55 mph) opera-

tion], and (f) average pennant sign cost of \$51 each, installed.

The marking cost based on 168 m of treatment of 4.6 m (15 linear ft)/12-m (40-ft) pattern, 8.2 cents/m, and an eight-month repainting schedule (1.5 times/year) is

$$\text{Annual cost} = 168 \text{ m} \times (4.6 \text{ m} \div 12\text{-m pattern}) \times \$0.082/\text{m} \times 12/8 = \$7.69/\text{zone}$$

The cost of the advance dotted line actually would be less than this value, because it would be placed at the same time the centerline is placed.

The expected sign costs, by using the \$51 pennant cost and a capital recovery factor of 0.205 (10 percent for seven years) is

$$\text{Annual sign cost} = \$51.00 \times 0.205 = \$10.46/\text{zone}$$

The expected total annual cost per no-passing zone is \$18.15, the sum of the marking and signing costs identified above.

Estimation of the Number of No-Passing Zones

The precise number of no-passing zones nationwide is not documented. In fact, this information was received from relatively few states in the FHWA survey. Therefore, it was necessary to estimate the number by using several sources of available data. Byington (6) reported that there are approximately 1.2 no-passing zones/km (2/mile) on two-lane highways in Virginia. This would translate to approximately 1 116 408 no-passing zones nationwide. The topography in Virginia suggests that this estimate is probably high for a nationwide estimate. By extrapolating from observation along 160 km (100 miles) of two-lane roadway in 28 states, an estimate of 835 000 no-passing zones was obtained.

The FHWA survey obtained data from four states. Based on an average of 9125 no-passing zones/state, a total national estimate would be 456 250. This figure

represents the smallest probable value that could reasonably be expected.

The three basic estimating procedures produced a wide range of estimates. The average is about 800 000, which compares favorably with the estimate obtained by sampling 160 km in several states. For this reason, the estimate of 835 000 no-passing zones was selected as the expected value and used throughout the economic analysis.

Estimation of the Benefits of the Advance No-Passing-Zone Treatment

Estimation of the Annual Number of Passing Maneuvers on Two-Lane Highways

The 1974 Highway Statistics (7) presents a summary of the length of two-lane roadway in each of several average daily traffic (ADT) classifications. The Highway Capacity Manual (8) presents a relationship between the peak loadings and the frequency with which the loadings occur on the two-lane highway system.

By multiplying the average percentage of the ADT by the midpoint value of the ADT ranges, expected hourly volumes for each ADT range can be obtained. By multiplying the number of hours represented by the peak-period percentage by the length of roadway in each ADT classification, hourly kilometers at each ADT level can be generated. By using relationships between total hourly volume and passes per kilometer per hour (9, 10), the average number of passing maneuvers for each ADT group can be determined. The product of the hourly kilometers at each ADT level and the average number of passing maneuvers for that group summed over all ADT groups produces an estimated 7451.2×10^6 passing maneuvers/year.

Estimation of the Number of Passing Maneuvers Performed with No On-Coming Vehicle in Sight

Normann (11) determined that 59.7 percent of all passing maneuvers were performed in the absence of an opposing vehicle. The product of this percentage and the total number of passing maneuvers performed (7451.2×10^6) provides an estimate of the number of passing maneuvers executed when available sight distance was the limiting factor (P_{SR}).

$$P_{SR} = 0.597 \times 7451.2 \times 10^6 = 4448 \times 10^6$$

Estimation of the Number of Passing Maneuvers That Involve Clipping

A study by the Michigan State Highway Department (12) revealed that clipping (completing the pass beyond the start of the solid yellow line) occurred in 14-17 percent of the total number of passing maneuvers on a two-lane highway. Assuming that 15 percent of passing drivers would clip in the normal passing situation and in the absence of opposing traffic, the total number of passing maneuvers for which the advance treatment could be beneficial is estimated as

$$P_{CLIP} = 0.15 \times 4448 \times 10^6 = 667 \times 10^6$$

This number represents the annual number of passing maneuvers on two-lane highways that end beyond the start of the no-passing zone.

Estimation of Passing Accidents That Involve an Illegal Sight-Restricted Passing Maneuver

Data from the Federal Aid Fatal and Injury Accident Rate Study in 1974 (13) reveal that the fatality and injury accident rates for rural federal aid highways were 1.99 and 37/100 million vehicle-km (3.2 and 59.5/100 million vehicle miles), respectively. The number of fatalities and injury accidents eliminated can be estimated by multiplying these rates and the annual vehicle kilometers. The total vehicle kilometer of travel per day was estimated as 849.1×10^6 (527.7×10^6 vehicle miles), which represents 309 800 million vehicle-km (192 600 million vehicle miles) annually; therefore,

$$\begin{aligned} \text{Fatal accidents} &= 1.99 \times 309\,800 \times 10^{-2} = 6160 \\ \text{Injury accidents} &= 37 \times 309\,800 \times 10^{-2} = 114\,600 \end{aligned}$$

The 1974 edition of Accident Facts (14) indicates that 19 300 fatal accidents, 230 000 injury accidents, and 2 240 000 PDO accidents occurred on rural state roads in 1973. This resulted in 420 000 injuries and 23 300 fatalities. Expanding the injury accident figures by the ratio of PDO accidents to injury accidents, an estimate of the number of PDO accidents on federal aid highways can be obtained:

$$\begin{aligned} \text{PDO accidents} &= (2\,240\,000 \div 230\,000) \times 114\,600 \\ &= 1\,116\,000 \end{aligned}$$

The distribution of two-lane-highway accident severity therefore becomes 6160 fatal accidents, 114 600 injury accidents, and 1 116 000 PDO accidents (total = 1 236 760 accidents).

A study conducted by the Franklin Institute Research Laboratories (9) concluded that approximately 10 percent of the accidents on two-lane roadways were related to passing. Therefore, an estimate of the total number of passing-related accidents is 10 percent of the values above:

$$A_{PASSING} = 0.10 \times 1\,236\,760 = 123\,676$$

The passing-related accidents in which sight distance is the visual restriction can be estimated by the product of the total passing-related accidents ($A_{PASSING}$) and the ratio of the number of passing maneuvers that involve clipping (P_{CLIP}) to the total number of passing maneuvers:

$$A_{CLIP} = 123\,676 \times [(667 \times 10^6) \div (7451 \times 10^6)] = 11\,071$$

Thus, an estimated 11 071 passing-related accidents occur annually in which the maneuver was initiated in the passing zone and involved an illegal sight-restricted completion.

Estimation of the Number of Accidents That Would Be Eliminated

The human-factors studies in this research indicated that approximately 74 percent of the subject drivers occasionally clip during the passing maneuver. Further, about 69 percent understood the meaning of the advance treatment without prior education. Thus, approximately 51 percent of the drivers (product of the two percentages) could be expected to respond correctly to the advance treatment system. The number of clipping accidents that could be expected to be eliminated through extensive use of the proposed advance no-passing-zone treatment can be estimated as

$$A_{ELIM_{low}} = 0.51 \times 11\,071 = 5646 \text{ accidents/year}$$

With minimal education, 94 percent correct understanding of the advance treatment was demonstrated (1). Therefore, the long-term effects could be estimated as

$$A_{ELIM_{high}} = 0.94 \times 0.74 \times 11\,071 = 7700 \text{ accidents/year}$$

Estimation of the Number of Lives Saved

The accident investigation (1) indicated that approximately 3.5 percent of all passing accidents involve a fatality. Applying this factor to the low and high estimates of accident reduction above produces an estimate of the number of fatalities that can be expected to be eliminated annually by application of the advance treatment:

$$\text{Fatalities eliminated}_{low} = 0.035 \times 5646 = 198$$

$$\text{Fatalities eliminated}_{high} = 0.035 \times 7700 = 270$$

Estimation of the Number of PDO and Injury Accidents Eliminated

PDO and injury accidents represent the difference between total accidents eliminated and the number of fatal accidents. Kemper and others (15) stated that 42 percent of the nonfatal passing accidents result in injury. The number of PDO and injury accidents eliminated can be estimated by applying this factor to the low and high estimates above:

$$\text{Injury accidents eliminated}_{low} = 0.42 \times (5646 - 198) = 2288$$

$$\text{Injury accidents eliminated}_{high} = 0.42 \times (7700 - 270) = 3121$$

$$\text{PDO accidents eliminated}_{low} = 0.58 \times (5646 - 198) = 3160$$

Estimation of the Potential Dollar Savings

NHTSA (16) estimated the total societal costs of automobile accidents at \$287 175 for fatalities, \$8085 for injuries, and \$520 for PDO accidents. By using these values, the expected annual savings for the United States as a result of using the advance no-passing-zone treatment can be estimated as

$$\text{Annual savings}_{low} = (198 \times 287\,175) + (2288 \times 8085) + (3160 \times 520) = \$77 \text{ million}$$

$$\text{Annual savings}_{high} = (270 \times 287\,175) + (3121 \times 8085) + (4309 \times 520) = \$105 \text{ million}$$

The annual dollar saving per no-passing zone in the nation is this saving divided by the total number of zones. As previously indicated, the low estimate of the number of no-passing zones in the United States is about 500 000; the high estimate is about 1 100 000; the most probable estimate is about 835 000. The estimated annual dollar savings per zone are shown below.

$$\text{Low estimate} = \$77\,000\,000 \div 1\,100\,000 = \$70/\text{zone}$$

$$\text{High estimate} = \$105\,000\,000 \div 500\,000 = \$210/\text{zone}$$

$$\text{Most probable estimate} = \$91\,850\,000 \div 835\,000 = \$110/\text{zone}$$

BENEFIT-COST COMPARISON

The annual cost per zone of the advance treatment is \$10.71 (low), \$22.11 (high), or \$18.15 (most probable). The expected benefit-cost ratio for the system is determined as the ratio of the savings to the annual cost of treatment. The following table presents these values and a summary of the economic analysis.

Item	Low Estimate	High Estimate	Most Probable Estimate
Annual cost per zone of advance treatment (\$)	10.71	22.11	18.15
Number of no-passing zones nationwide	456 250	1 116 400	835 000
Number of accidents eliminated by advance treatment	5646	7700	6673
Fatalities eliminated	198	270	234
Injury accidents eliminated	2288	3121	2704
PDO accidents eliminated	3160	4309	3734
Annual savings resulting from advance treatment (\$000 000s)	77	105	92
Annual savings per zone (\$)	70	210	110
Benefit-cost ratio of advance treatment	3.2	19.6	6.1

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Publication of this paper sponsored by Committee on Operational Effects of Geometrics.