Economic Analysis of Alcohol Safety Countermeasures

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This paper discusses a 10-month study performed for the National Highway Traffic Safety Administration. The purpose of the study was to conduct a detailed benefit-cost analysis of seven alcohol safety countermeasures. This analysis determined the potential for successful implementation of each countermeasure in terms of the estimated cost-effectiveness and provided base-line information for research funds allocated for the development of countermeasures. The countermeasures analyzed were the sober pill, self-tester, evidential roadside tester, noncooperative breath tester, alcohol safety interlock system, continuous monitoring device, and operating-time recorder. A set of benefit/cost ratios was calculated for each countermeasure. Sensitivity analyses were performed on the crucial assumptions and key elements of costs and benefits to test their impact on the benefit/cost ratios. The potential for successful application of each countermeasure was assessed on the basis of the benefit/cost ratios and social, technological, and legal feasibility. All seven countermeasures are either in the conceptual or the experimental testing stages of development. Due to the paucity of reliable data, the findings of the analysis focused on the requirements for economic feasibility (a benefit/cost ratio in excess of 1) rather than individual feasibility. The values for critical parameters were determined and used to find the cost-effectiveness for each countermeasure. Specific recommendations for each countermeasure are made regarding further research.

The research described in this paper was sponsored by the National Highway Traffic Safety Administration (NHTSA) (1). The purpose of the study was to conduct a detailed benefit-cost analysis of seven alcohol safety countermeasures. This analysis determined the potential for successful implementation of each countermeasure in terms of the estimated cost-effectiveness and provided NHTSA with base-line information so that research funds can be allocated for countermeasure development. The countermeasures analyzed were the sober pill, self-tester, evidential roadside tester, noncooperative breath tester, alcohol safety interlock system, continuous monitoring device, and operating-time recorder. This paper describes the methodologies developed for estimating the benefits and costs of the countermeasures and summarizes the results, conclusions, and recommendations of the study.

A brief description of the physical and operational characteristics for each countermeasure is given in Table 1. The physical characteristics refer to what the device is, how it works, and what the current stage of development is; the operational characteristics refer to how the countermeasure will be used by the target population.

A set of benefit/cost ratios for the countermeasures was calculated on the basis of the mode or scale of application (restricted or universal). To test the impact of benefit/cost ratios, sensitivity analyses were performed on the crucial assumptions and key elements of cost and benefit. The potential for successful application of each countermeasure was assessed on the basis of the benefit/cost ratios and social, technological, and legal feasibility.

BENEFIT MEASUREMENT

The potential benefit of each countermeasure was estimated by using the empirical relationships derived by Hurst (2, 3), which measured the impact of estimated changes in breath-alcohol concentration (BAC) levels on crashes and fatalities. The standard societal costs of crashes and fatalities adopted by the U.S. Department of Transportation (DOT) were applied to the reduction projections for estimating the benefits in dollar terms, i.e., \$200 000/fatality, \$7200/personal injury, and \$300 property damage/crash. (DOT has revised the societal cost estimates to \$234 900/fatality, \$11 200/personal injury, and \$500 property damage/crash.)

Measure of Effectiveness

The measure of effectiveness used for estimating potential benefits was the reduction in alcohol-related crashes. The formula for calculating net benefits with this approach is

$$B = \$7200(\Delta I) + \$300(\Delta K) + \$200\ 000(\Delta F') \quad (1)$$

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Table 1. Physical and operational characteristics of countermeasures.

	Characteristics	
Countermeasure	Physical	Operational
Sober pill	A drug that would reduce the impairing effect of alcohol on driver performance. The drug is currently in the conceptual stage of development.	The drug would be nonprescription, taken orally and made available to the public for voluntary use.
Self-tester	A fixed or portable device for unsupervised use by drivers that measures breath-alcohol concentration (BAC). Prototype devices are currently available.	The device would indicate when driving should be avoided (hazardous BAC level) and made available to the public for voluntary use by drivers.
Evidential road tester	A portable device that accurately measures and records BAC levels. Prototype devices are currently available.	The device would be used by police on patrol duty; it would eliminate the need for trips to the police station if the driver did not register a high enough BAC level. The BAC readings could also be used as evidence in court.
Noncooperative breath tester	A device that would detect the presence or absence of alcohol on the driver's breath without his active cooperation. The technology exists for such a device, but prototype devices are not available at this time.	The device would be used by police as a prearrest screening test for alcohol levels.
Alcohol safety interlock system	An in-vehicle device that tests the driver (BAC and related performance) before allowing the vehicle to start. Prototype devices are currently available.	The device would either be assigned by the courts on a restricted basis to cars of DWI[a] offenders or be installed on a universal basis to all new passenger vehicles.
Continuous monitoring device	An in-vehicle device that monitors BAC-related driving performance. When performance is unacceptable, a warning signal is given and recorded. This device is currently in the conceptual stage of development.	The device would be assigned by the courts to cars of DWI offenders. The device would permit voluntary discontinuation of driving after the warning is given; noncompliance would result in penalty.
Operating-time recorder	An in-vehicle device that would record the time of day and day of the week when the vehicle is driven. The technology exists for such a device, but prototype devices are not available at this time.	A device that would be assigned by the courts to cars of DWI offenders. The driver would be restricted from operating the vehicle during high-risk hours. The device would monitor compliance; noncompliance would result in penalty.

[a]DWI = driving while intoxicated.

Table 2. Potential savings from alcohol-related crashes.

Item	Total Number of Crashes	Alcohol Related (%)	DOT Societal Costs ($)	Potential Savings (billions of $)
Fatalities	57 000	0.50	200 000	5.70
Injuries	5 189 000	0.30	7 200	11.21
Property damage	24 850 000	0.15	300	1.12
Total				18.03

Table 3. Breath alcohol concentration by time of day and day of week.

BAC Level (%)	Night During the Weekend	Night During the Week	Day During the Weekend	Day During the Week	Average
0.00 to 0.01	0.773	0.809	0.901	0.941	0.878
0.02 to 0.04	0.092	0.077	0.040	0.024	0.049
0.05 to 0.07	0.061	0.051	0.027	0.016	0.032
0.08 to 0.09	0.024	0.020	0.010	0.006	0.013
0.10 to 0.14	0.036	0.031	0.016	0.009	0.020
0.15 or more	0.014	0.012	0.006	0.004	0.008

where

ΔI = average number of injuries per alcohol-related crash,
ΔK = number of alcohol-related crashes, and
$\Delta F'$ = average number of fatalities per alcohol-related crash.

To apply the formulas for calculating the savings in societal costs that would result from implementing a countermeasure, it was necessary to estimate the number of personal injuries per alcohol-related crash and the number of fatalities per alcohol-related crash. The percentages shown in Table 2 (4) were used in the following manner to obtain the estimates.

$$\Delta K = 0.15 \times 24\ 850\ 000 = 3\ 727\ 500$$
$$\Delta F' = 0.5 \times 57\ 000 = 28\ 500$$
$$\Delta F'/\Delta K = 28\ 500/3\ 727\ 500 = 0.007\ 65$$
$$\Delta I = 0.3 \times 5\ 189\ 000 = 1\ 556\ 700$$
$$\Delta I/\Delta K = 1\ 556\ 700/3\ 727\ 500 = 0.417\ 6$$

Hurst has demonstrated that the relative probability for accident involvement can be 19 times higher for drivers with BAC level greater than 0.15 than for sober drivers. Therefore, countermeasures that focus on reducing the number of drivers with elevated BAC levels will have a greater than average impact on reducing the number of alcohol-related fatalities and personal injuries (2). According to Hurst's estimates, the appropriate values for the average number of fatalities per alcohol-related crash and the average number of personal injuries per alcohol-related crash are twice those for all crashes. To provide a range of values for the analysis, calculations for each countermeasure were made by using the average number per alcohol-related crash as the lower or pessimistic estimate and the Hurst estimate as the upper or optimistic estimate. The values for fatalities per alcohol-related crash ($\Delta F'/\Delta K$) were: average estimate = 0.007 65 and Hurst estimate = 0.001 52. The values for personal injuries per alcohol-related crash ($\Delta I/\Delta K$) were: average estimate = 0.4176 and Hurst estimate = 0.8352.

Requirement for BAC Data

To apply the Hurst methodology, the expected savings in crashes was estimated by using the overall distribution of BAC levels and the distribution of BAC levels for people involved in crashes. To assess the total effectiveness of the countermeasures, BAC data that represented driving during all hours of the day and each day of the week were needed. The four primary sources that were reviewed and assessed for data on the overall BAC distribution were

1. U.S. National Roadside Breathtesting Survey (1973),
2. Accident and Control Data, Grand Rapids, Michigan (1963),
3. Alcohol Safety Action Program (ASAP) Baseline Data, Washtenaw County, Michigan (1965), and
4. ASAP Data Tapes, NHTSA (1973).

The three primary sources that were reviewed and assessed for data on the BAC distribution in crashes were

1. Accident and Control Data, Grand Rapids, Michigan (1963),

2. ASAP Data, Nassau County, New York (1970), and
3. ASAP Data Tapes, NHTSA (1973).

The assessment of the data sources revealed that the U.S. National Roadside Breathtesting Survey provided the best representative data for determining the overall BAC distribution nationally, while only the Accident and Control Data from Grand Rapids provided the combination of both overall BAC distribution data and data on BAC distribution in crashes. The Hurst methodology that estimated the accident-reducing potential of the various countermeasures requires the use of consistent data for both of these categories in a given area. It would have been desirable to use the national data to compare BAC distributions for crash and control groups, but the data services were limited. Therefore, it was assumed that the relative probability of crash involvement is strictly a function of alcohol consumption and that differences due to geographic variations are not statistically significant. Further data are required to test the validity of this assumption.

No BAC distribution data were available for the day of the week, the night of the week, and the day during the weekend; therefore, a methodology was developed for estimating time distribution. The procedures for deriving these BAC distributions are presented in the General Research Corporation's (GRC) final report (1).

COST MEASUREMENT

The cost element in the benefit/cost ratio is the cost of developing, producing, and implementing the countermeasures. Only incremental costs were considered in the analysis. Costs already incurred by research and development of countermeasures are sunk costs and are not relevant for comparing the costs and benefits of implementing the countermeasure. Only those future costs that are directly attributable to countermeasures were included. In addition to excluding sunk costs, all costs and benefits that would have occurred regardless of whether the countermeasure was undertaken were excluded. For example, increased court costs associated with the evidential roadside tester were measured by subtracting the total court costs without the countermeasure from the total court costs if the countermeasure were in use.

Since many of the countermeasures are in the early stages of development, reliable cost data do not exist; therefore, expert opinion was relied on to obtain estimates. Several interviews were held with prominent individuals familiar with the research and development of the countermeasures. Ten elements of cost were considered: research and development; manufacturer's selling price; installation costs; maintenance costs; inspection costs; testing equipment; cost of malfunction; public information; increased enforcement costs of police, courts, and corrections; and removal costs.

In order to provide a basis for comparing the benefits and costs of each countermeasure, a period comparison or estimated economic life for each countermeasure had to be determined. A period of 10 years was used for the analysis.

Since costs and benefits accrue at different rates over time, discounting was used to take into account the time value of money. All costs and benefits were discounted to the present, and the benefit/cost ratios were stated in terms of average annual benefits and costs. The Office of Management and Budget has chosen a rate of 10 percent for use in discounting cash flows for all projects that involve the expenditure of federal funds (5). This rate was used for the countermeasures.

Accident trends over the next 10 years were given consideration. From 1960 to 1970, the number of vehicles on the road increased from 73 869 000 to 108 375 000 and the number of accidents increased from 11 429 000 to 22 116 000 (6). The potential for reducing accidents in 1970 was therefore substantially greater than in 1960. If this trend continues, the potential for reducing accidents in 1985 would be greater than in 1975. However, the amount of driving will not increase nearly as rapidly over the next 10 years, because of the energy crisis and the presidential decision to reduce the rate of gasoline consumption over the next few years. A conservative approach was taken and it was assumed that the potential for accident reduction in 1975 would be the same as that for each year through 1985. This assumption applies to all countermeasures and does not affect the relative ranking of the benefit/cost ratios.

HURST'S METHODOLOGY

Hurst's epidemiological model was used to estimate the accident-reducing potential for each countermeasure (2). This model uses the overall BAC distributions, the BAC distributions in crashes, and the application of Bayesian statistics to determine the relative likelihood that a driver will be involved in an accident at different BAC levels. The relative probabilities are based on empirical evidence derived by Hurst that drivers with higher BAC levels have a greater likelihood of being involved in an accident than drivers with lower BAC levels.

Assumptions

The major assumption underlying the Hurst relationship between BAC and crashes is that someone driving with a BAC level of 0.20 percent would, if driving with a lower BAC (e.g., 0.10 percent), have the same relative likelihood of crash as someone who ordinarily drove with a lower BAC. Thus, if it can be demonstrated that a proposed alcohol countermeasure (e.g., the alcohol interlock), can effectively reduce the average BAC for those who use the countermeasure, then empirical relationships are established and can be used to estimate the expected reduction in accidents.

The Hurst model also assumes that the relative probability of a crash at varying BAC levels reflects only the causal influence of the alcohol ingested and, therefore, that drivers with higher BAC levels have a greater likelihood (probability) of being involved in an accident than drivers with lower BAC levels.

Model

The Hurst model for estimating the expected reduction in crashes (C) by lowering the BAC level from B to P is

$$\Delta I_p = \sum_{B=P}^{K} I_B \left\{ [RP(C/B) - RP(C/P)] / RP(C/B) \right\} \qquad (2)$$

where

ΔI_p = expected reduction in crashes from the application of the countermeasure that reduced the BAC from B to P,
I_B = expected number of crashes that would occur at a BAC level of B without the application of the countermeasure,
K = maximum value of BAC obtainable in the sample,
RP(C/B) = relative probability of a crash at a BAC level of B, and
RP(C/P) = relative probability of a crash at a BAC level of P.

The relative probability of C given B is

$$RP(C/B) = [P(C/B)]/[P(C/B_O)]$$
$$= \{[P(C)P(B/C)]/[P(B)]\} / \{[P(C)P(B_O/C)]/[P(B_O)]\}$$
$$= [P(B_O)P(B/C)]/[P(B)P(B_O/C)] \quad (3)$$

where

$P(B_0)$ = absolute probability of observing a BAC level of 0.00 to 0.01 percent,
$P(B)$ = absolute probability of observing a BAC level of B,
$P(B_0/C)$ = conditional probability of observing a BAC level of 0.00 to 0.01 percent, given that a crash has occurred, and
$P(B/C)$ = conditional probability of observing a BAC level of B, given that a crash has occurred.

The first two probabilities may be empirically derived from the overall BAC distributions given in the Accident and Control Data, and the last two conditional probabilities may be empirically derived from the BAC distributions in crashes that are also given in the Accident and Control Data.

In the application of the Hurst model to the individual countermeasures, the following relative probabilities were derived from the Accident and Control Data.

BAC Level (%)	Relative Probability	BAC Level (%)	Relative Probability
0.00 to 0.01	1.0	0.08 to 0.09	1.933
0.02 to 0.04	1.0	0.10 to 0.14	5.74
0.05 to 0.07	1.36	0.15 or more	18.97

A relative probability of 5.74 for BAC = 0.10 to 0.14 percent means that, under similar traffic conditions and at the same time of day, a driver with this BAC level would be 5.74 times more likely to be involved in an accident than a driver with a BAC level of 0.00 to 0.01 percent. A driver with a BAC level of 0.08 to 0.09 percent would be only 1.933 times more likely to be involved in an accident than this latter driver. Thus, if a driver were shifted from BAC = 0.10 to 0.14 percent to BAC = 0.08 to 0.09 percent, his risk of being involved in an accident is 33 percent of what it was at the higher BAC level. The potential saving is equal to 66 per cent of the cost of crashes at the higher BAC level [(5.74 - 1.933)/5.74 = 0.66].

The remaining tasks were to estimate the impact of the countermeasure's use on the BAC levels of those using it and to estimate the number of crashes ($\hat{I}_B$) that would potentially be affected by the application of the countermeasure. If the application of the alcohol safety interlock is 100 percent effective, then to prevent a driver with a BAC greater than 0.09 percent from driving the limit is set at 0.1. The Hurst formula is used to calculate the expected reduction in accidents by reducing the BAC level from 0.10 to 0.14 percent and 0.15 or more to 0.09 percent. Since only a limited number of drivers have the device, then I_B must be adjusted to reflect the crashes that are potentially affected ($\hat{I}_B$). This adjustment was made in the following manner:

$$\hat{I}_B = \{[P_B(912.5)X]/(T_B)\}\ I_B \qquad T_B = P_B T \quad (4)$$

where

P_B = proportion of drivers at BAC level B,
912.5 = average number of trips per person (2.5) per year (365 d) (7),
X = number of drivers who have the device,
T = total number of trips per year,
T_B = total number of trips per year at a BAC level of B, and
I_B = number of crashes per year at a BAC level of B.

For each countermeasure, it was necessary to calculate an adjusted I_B ($\hat{I}_B$) to reflect the number of trips per year that are potentially affected by the application of the countermeasure. The concept of the trip is the weighting factor rather than exposure to distance. Although distance can be used as the weighting factor, many of the countermeasure devices focus on preventing a trip from occurring, and many of the costs are directly proportional to the number of trips rather than the distance traveled. Furthermore, if the total number of trips in the aggregate for all licensed drivers is closely correlated with distance, then weighting factors based on the number of trips would be identical to those based on distance.

The Accident and Control Data crash distributions were used to estimate the total number of crashes at each BAC level as shown in the following:

BAC Level (%)	Crash Probability	Crashes (I_B)
0.00 to 0.01	0.8654	21 505 190
0.02 to 0.04	0.0364	904 540
0.05 to 0.07	0.0221	549 185
0.08 to 0.09	0.8130	323 050
0.10 to 0.14	0.0310	770 350
0.15 or more	0.0318	790 230

Generation of BAC Distribution

As was previously mentioned, BAC data were available for only night versus weekend periods; therefore, estimates were made for BAC distributions for day of the week, day during the weekend, and night of the week. The existing data from the National Roadside Survey were used as the baseline, and supplementary data from the Accident and Control Data, Zylman (8), and the ASAP Data Tapes were used to estimate the overall BAC distributions. The procedures followed are described in detail in the GRC final report (1). The estimated BAC distributions by time of day and day of the week are given in Table 3. The total BAC distribution is not a simple average of the time of day or day of the week distributions but rather a weighted average in which the weights are based on the percentage of trips associated with each.

RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Sober Pill

The sober pill would be cost-effective (benefit/cost ratio in the range of 4.0 to 5.0) if single doses cost 25 cents and it effectively reduced the BAC level by 0.04 to 0.05 percent. The critical considerations in determining the cost-effectiveness of the sober pill are that

1. It must be technologically feasible,
2. It must not have undesirable side effects,
3. It must be used for at least 1 out of 17 000 trips when the driver's BAC level is 0.05 percent or greater, and
4. A single dose must not cost more than $1.

It was recommended that NHTSA sponsor additional research to develop a drug that can reduce the BAC level by 0.04 to 0.05 percent without producing undesirable side effects and to develop implementation procedures.

Self-Testers

Self-testers would be cost-effective (benefit/cost ratio in the range of 1.0 to 2.0) if users did not drive 75 percent of the time that their BAC levels were 0.10 percent or greater. The critical considerations in determining the cost-effectiveness of the self-testers are that

1. The driver deterrence rate is unknown,
2. The self-tester must be used for at least 1 out of 10 000 trips when the driver's BAC level is 0.10 percent or greater, and
3. The cost per use must not exceed 80 cents.

It was recommended that NHTSA sponsor additional research to determine the expected public use and level of deterrence under different conditions and to develop implementation procedures.

Evidential Roadside Tester

The evidential roadside tester would be cost-effective (benefit/cost ratio in the range of 1.0 to 2.0) if it deterred 1 to 2 percent of trips that would otherwise be made with a BAC of 0.10 percent or greater. The critical considerations in determining the cost-effectiveness of the evidential roadside tester are that

1. The potential for driver deterrence is unknown,
2. The acceptance and use by law enforcement agencies are unknown,
3. At least 100 units must be in service each year,
4. The incremental court costs per case must not exceed $100, and
5. The incremental rehabilitation costs per case must not exceed $250.

It was recommended that NHTSA sponsor additional research to determine the deterrence potential, determine the willingness of the police and courts to use the device, and develop implementation procedures.

Noncooperative Breath Tester

The noncooperative breath tester would be cost-effective (benefit/cost ratio in the range of 1.0 to 2.0) if it deterred 1 to 2 percent of trips that would otherwise be made with a BAC level of 0.10 percent or greater. The critical considerations in determining the cost-effectiveness of the noncooperative breath tester are that

1. The driver deterrence rate is unknown,
2. The tester must comply with existing legal constraints (laws against illegal search and seizure),
3. At least 100 units must be in service each year,
4. The incremental court costs per case must not exceed $75, and
5. The incremental rehabilitation costs per case must not exceed $200.

It was recommended that NHTSA sponsor additional research to determine the potential for deterrence, develop a device that meets the performance and cost specifications, assess the legal constraints, and develop implementation procedures.

Alcohol Safety Interlock System

The alcohol safety interlock system would be cost-effective (benefit/cost ratio in the range of 1.0 to 2.0) if a device could be developed that had at least 50 percent effectiveness at a BAC level of 0.10 percent or greater, was tamperproof, and required minimal maintenance and installation cost. The critical considerations in determining the cost-effectiveness of the alcohol safety interlock system are that

1. The effectiveness rate must be at least 50 percent,
2. The courts must be willing to impose its use (if it is restricted to DWI offenders),
3. The annual maintenance cost must not exceed $10 per unit,
4. The installation and removal costs for restricted use must not exceed $15.00 and $7.50, respectively,
5. There must be no inspection cost, and
6. If it is used on a restricted basis, at least 1000 units/year must be in service.

It was recommended that NHTSA sponsor additional research to develop a device that meets the stated performance and cost requirements, determine the potential for deterrence, determine the court's willingness to impose restricted use of the device, determine the potential for social acceptance of universal use, and develop implementation procedures.

Continuous Monitoring Device

The continuous monitoring device would be cost-effective (benefit/cost ratio in the range of 1.0 to 1.5) if drivers who have the device abide by the warning 50 to 60 percent of the time. The critical considerations in determining the cost-effectiveness of the continuous monitoring device are that

1. The device must be technologically feasible,
2. The driver-deterrence rate is unknown,
3. The courts must be willing to impose its use,
4. At least 10 000 units must be in service a year,
5. The manufacturing price must not exceed $175 to $200 per unit, and
6. The installation and removal costs must not exceed $15.00 and $7.50, respectively.

It was recommended that NHTSA sponsor additional research to develop a device that correlates driving impairment with the BAC level, determine the potential for deterrence, determine the court's willingness to impose the use of the device, and develop implementation procedures.

Operating-Time Recorder

The operating-time recorder would be cost-effective (benefit/cost ratio in the range of 1.0 to 2.0) if it were 50 to 60 percent effective in eliminating trips made with a BAC level of 0.10 percent or greater during restricted hours. The critical considerations in determining the cost-effectiveness of the operating-time recorder are that

1. The driver deterrence rate is unknown,
2. The courts must be willing to impose its use,
3. The restricted hours must encompass the time when at least 50 percent of the driving that might be influenced by alcohol would be done,
4. At least 10 000 units must be in service each year,
5. The annual maintenance and calibration cost must

not exceed $10.00 per unit, and

6. The installation removal costs per unit must not exceed $15.00 and $7.50, respectively.

It was recommended that NHTSA sponsor additional research to determine the potential for deterrence, determine the court's willingness to impose the use of the device, and develop implementation procedures.

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