

Cost outcome analysis in injury prevention and control: a primer on methods

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Investments in public programs typically are constrained by a desire for fiscal responsibility. Decision makers are interested in knowing if an investment produces desired results less expensively than alternative approaches, or if an investment's benefits exceed its costs. They may want to determine whether a particular program is worthwhile to implement (a prospective approach), or whether a program that has already been implemented has been worth its cost (a retrospective approach). World wide, concerns about health care costs have pressed these issues to the forefront.

Cost outcome analyses generally develop a measure of the cost per positive outcome from an intervention. By expressing outcomes in a common metric, such analyses often clarify murky resource allocation decisions. For example, is it more important to fix the swings, which will prevent five broken arms a year, or the seesaws, which will prevent four sprained ankles and two broken legs a year? Should we flatten the curve on High Street, which will prevent one pedestrian death every four years, or add a shoulder on Rose Street, which will prevent five hospitalizations a year?

Besides helping to compare different interventions, cost outcome analyses help to identify the consequences and costs of a particular intervention. An injury prevention program may not only lead to the avoidance of injury and death and associated medical costs, but also a reduction in property damage, work loss, and pain and suffering. The costs of implementing the program include not only direct expenditures on salary, equipment and space, but also other uncoded resources such as volunteer time or public resources such as police time. Program costs and outcomes may sometimes be broken down into who actually bears the burden: health care providers, potential victims of injury, or taxpayers through additional government costs.

To deal with such challenging questions, three types of cost outcome analyses (table 1) are available:

Cost effectiveness analysis (CEA) expresses the outcome in a convenient and useful measure, for example, per life saved or per scald burn prevented. The findings are normally expressed as ratios, such as the *cost per year of life saved* or the *cost per injury avoided*.

Cost utility analysis (CUA) extends cost effectiveness analysis by including different uncoded outcome measures, weighted by a common unit. The common unit is usually a quality adjusted life year, or QALY.¹ QALYs (and variants, like the World Bank's disability adjusted life years), are scales that value a year in any given health state between death (with value 0) and perfect health (with value 1), based on a representative individual's prefer-

ences among different health states. QALYs reflect not only years of life saved but also the degree of functioning and health during those years. They do not reliably measure out-of-pocket cost savings due to care. Thus, it is generally desirable to subtract these savings (for example, reduced property loss and medical costs savings) from the cost term when computing a cost utility measure.

Cost benefit analysis (CBA) places dollar values on all significant outcomes, including death, pain and suffering, and property loss, so that benefits are directly compared with costs in monetary terms. Reporting costs and outcomes in a common metric facilitates comparison over diverse programs, and allows the benefits to be clearly distinguished from the costs. (A CUA may be translated into a CBA by placing a dollar value on QALYs.²⁻⁵)

We describe the steps in a cost outcome analysis, including the choice of perspective and the injury cost components relevant when valuing injury prevention. A benefit cost analysis of smoke detectors illustrates the methodology. We then discuss common errors in cost outcome analysis, and conclude with some recommendations.

Steps in a typical cost outcome analysis

Methods for safety benefit cost analysis are described in great depth elsewhere.^{1,6-9} We summarize here for a non-technical audience. The approach includes the following steps:

(1) DEFINE THE INTERVENTION

Determine the specific program or group of programs to be evaluated, the target population or populations who are intended to be affected by the different outcomes, and the time horizon over which the costs and benefits are defined.

(2) CHOOSE THE PERSPECTIVE OR PERSPECTIVES THE ANALYSIS WILL TAKE

Different decision makers or audiences may have different perspectives, including that of society, society excluding the person who caused the injury (for example, a drunk driver), government, or other interest groups. The perspective should be explicitly stated.^{6,10} It is generally desirable to present a societal perspective that takes into account costs and benefits to all members of society. This perspective is the most relevant for public decision making. Much of the medical literature just estimates the net effect on medical spending; this constitutes an analysis from the perspective of the health care system or the agencies that finance health care. It ignores the value of the good health produced.

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(3) CHOOSE HOW TO ADJUST FOR DIFFERENT VALUES OF MONEY OVER TIME

When valued at current prices, the value of costs or benefits of an intervention generally increase in time due to price inflation. Therefore, they should be adjusted to prices in a common base year. In addition, costs of an intervention made in the future, or benefits only to be received in the future, are of lesser value, because money can earn interest when invested or deposited in a savings account and because the future is uncertain. Therefore, future costs and benefits should be discounted to their present value. (US courtrooms currently use discount rates between 1% and 3% for work losses and ancillary costs, and 0% for future medical costs. Governments use much larger discount rates, 4–8%.) Some suggest a discount rate of 3% for analyses using a societal perspective; our studies use a 2.5% discount rate.^{6 7 11}

(4) ESTIMATE THE COSTS OF THE INTERVENTION

Direct expenditures at the market price are often used to value resources because this

information is readily available. Waiting, other lost time, volunteer time, or donated facilities have no monetary value but, because the time and donated facilities could possibly have been used in some other way, for example by another intervention, they have a measurable value. This is computed in terms of *opportunity costs* by taking the next best possible use of those resources. For example, donated space is costed at its rental value, and volunteer labor is valued at the hourly wage that would be required to obtain the service. Allocation of overhead costs shared with other programs (for example, office space or administrators) and capital costs (for example, for computers or machinery) also require special attention.^{1 12} It may be inappropriate to include overhead costs, if, for example, the intervention would not affect administrator's time or the application of machinery to other uses. It is important to include additional, or *marginal*, cost of implementing the program. The costs included also depend on the perspective of the decision maker; for example, volunteer time may not be relevant from a government perspective.

(5) CHOOSE THE RELEVANT OUTCOMES

Identify the injuries that the intervention could prevent, and any non-medical outcomes that may be relevant. For example, a traffic safety intervention may reduce property damage or the need for other publicly funded programs (for example, police services). An intervention that reduces handgun availability may also reduce property damage (from fewer robberies) or the need for public programs aimed at criminal sanctions.

When the outcomes are presented in monetary terms (for example, a CBA), the benefits of injury reduction are stated as reduced injury costs. Table 2 presents the costs that may be saved. Injuries often involve loss of work, and generally, involve pain and suffering. Interventions may lead to reduced property damage and public program costs. Of the cost savings, the value of pain and suffering and lost quality of life is the most controversial. Some analyses, such as those using the cost of illness approach, exclude lost quality of life; they simply value the loss of life by lost wages.¹³ Because pain and suffering are estimated less directly than other costs, valuations of reduced pain, suffering, and lost quality of life may be reported separately from other benefits.¹⁴ (There is a growing trend toward including quality of life in costs in transport analyses in the developed world.¹⁵)

We generally classify benefits into three categories: medical, other tangible or monetary, and quality of life. Sometimes, non-injury costs, such as property damage avoided or travel time savings are distinguished. The outcomes included depend on the perspective. For example, social costs include all those in table 2, except for the non-administrative portion of welfare and other transfer payments. The government perspective includes transfer payments, government medical care payments, and lost tax payments from individuals and

Table 1 Differences in cost outcome methodologies

Type of study	Identification of effects	Measurement of effects
CEA	Single effect of interest to alternative strategies, but achievable to different degrees	Natural units (for example, life years gained, days saved, injuries avoided, accidents prevented)
CUA	Single or multiple effect, not necessarily common to alternative strategies, and common effects may be achieved to different degrees	QALYs or healthy days
CBA	Single or multiple effects, not necessarily common to alternative strategies, and common effect may be achieved to different degrees	Dollars

Table 2 Potential cost savings from injury interventions

Type of cost	Costs included	Measurement
Medical care costs	Health care expenses due to personal injury and illness	Payments for hospital and physician care, as well as rehabilitation, mental health care, prescriptions, allied health services, and medical devices. Coroner and premature burial costs for fatalities, and the costs of medically related loss compensation through insurance and the courts also may be included
Property damage and loss	Property damaged or lost during the injury incident	Value of property damage and of property taken and not recovered, plus administrative costs of processing insurance claims for property losses
Cost of public programs	Increased criminal justice and social service expense, reduced welfare payments, and reduced use of emergency services	Costs of emergency services, the criminal justice system, social services, and of administering payments under disability insurance and welfare programs. Emergency services include police, fire, ambulance, and helicopter services. Some studies include emergency medical transport costs in medical costs instead
Lost future work	Work lost by victims and their families, and increased employee recruitment and training costs	Wages, fringe benefits, housework, and possibly school days lost by the victims and their families, as well as life insurance and workers' compensation claims processing costs. Also included is the value of productivity lost by coworkers and supervisors recruiting and training replacements for disabled workers
Pain, suffering, and lost quality of life	Value of the pain, suffering, and lost quality of life that victims and their families experience due to injury, illness and death	For non-fatal injury and illness, the value is based on jury awards and settlements, or estimated from QALYs lost. For fatalities, the value is computed from the amount people routinely spend to reduce their risk of death

businesses. It excludes most property damage, other medical payments, lost wages, and pain and suffering.

(6) ESTIMATE THE EFFECT OF THE INTERVENTION ON OUTCOMES

The effectiveness estimate is often based on the percentage reduction in incidence or harm. The effects are generally estimated using statistical analyses, but may be inferred from studies of similar programs by others. The incidence of a particular outcome often depends on the percentage of cases attributable to the problem addressed by the intervention, for example, drunk driving.

(7) CALCULATE THE BENEFITS

The outcomes reflect the savings from the intervention. The benefits are the estimated number of injuries or incidents prevented, the associated QALYs, or cost savings. When outcomes are expressed as a percentage reduction in incidence, the benefits are estimated by multiplying the total incidence (or costs or QALYs) in the target population before the intervention by this percentage.

(8) COMPUTE THE COST OUTCOME RATIO

For CBA, the cost outcome ratio is obtained by dividing expected benefits by expected costs. This ratio is useful for comparing programs. It may also be useful to compute the difference between benefits and costs—a measure of the net savings (or losses) from the program. For CEA and CUA, the net program costs (costs minus dollar benefits) is divided by the outcome to yield a measure such as cost per crash averted, or cost per QALY.

(9) DESCRIBE ANY UNQUANTIFIED COSTS AND BENEFITS

Potential costs and benefits outside the time frame of the analysis, affecting other than the target population, or from more widespread adoption of the intervention need to be considered, even if a dollar value cannot be placed on these effects.

(10) ANALYZE WHO BENEFITS AND WHO PAYS

Estimate who bears the costs of the intervention, and who gets the benefits (for example, government, insurers).

(11) CONDUCT A SENSITIVITY ANALYSIS

Show how the results vary when parameters (for example, the discount rate, intervention effectiveness) change. It also may be useful to show how the estimates depend upon assumptions made in deriving the effects of the intervention, for example, that the reduction in one type of harmful behavior, such as drinking while driving, does not lead to other types of harmful behavior, such as illicit drug use.

An example: a benefit cost analysis of a smoke detector program

This section presents, as an example, a previously unpublished benefit cost analysis of a program to encourage the use of smoke detectors. It follows the steps listed in the preceding section.

(1) DEFINE THE INTERVENTION

The intervention estimates the return on the retail purchase, installation, and maintenance of smoke detectors for all US homes (or a typical US home). An average home requires 1.6 smoke detectors. We assume these are used for five years (the typical warranty period, but lower than the detector's 12 year useful life).^{16 17}

(2) WHAT IS THE PERSPECTIVE?

We examine smoke detector purchase from a societal perspective and document the effect on insurance costs.

(3) HOW ARE FUTURE VALUES ADJUSTED?

Benefits and costs are projected over a five year period, and are, therefore, discounted at 2.5%. (This rate lies at the conservative end of the 1–3% range the US Supreme Court considers unassailable in determining tort liability compensation.) Benefits are measured in current dollars, so need not be adjusted for inflation.¹⁸

(4) WHAT DOES A SMOKE DETECTOR COST?

Smoke detector costs include the purchase price, maintenance cost, and time spent purchasing, buying batteries and other maintenance. In the US, 1.6 smoke detectors cost \$12 including batteries. Replacement batteries in years 2–5 cost \$3 per year for 1.6 smoke detectors. In addition, we estimate 1.5 hours to buy and install the detectors, and 10 minutes yearly to buy and install replacement batteries. Time spent on home repair and maintenance, like other household work time, typically is valued at the hourly wages that people pay if they hire someone.¹⁹ From US Department of Labor statistics, the average hourly wage for home repair is \$9.24 (in 1994 dollars). With a five year life, the present value of detector costs per home is \$42.90. This consists of \$12 purchase price plus \$13.86 (1.5 hours × \$9.24) for installation plus \$17.04—the present value over years 2–5 of a \$3 annual battery purchase plus \$9.24/6 for battery purchase and installation. (Undiscounted, the battery related costs are \$18.16.)

Installing smoke detectors in 90.9 million US homes would cost about \$3.9 billion. This includes \$2.15 billion in out-of-pocket costs and time valued at \$1.75 billion.

(5) HOW LARGE IS THE RESIDENTIAL FIRE TOLL?

IN 1991, US Vital Statistics recorded 5317 deaths in residential fires (from burns, anoxia,

or other injuries). Miller *et al* estimated non-fatal fire injury counts by level of medical treatment from the National Fire Incident Reporting System, the National Hospital Discharge Survey (NHDS), and the National Electronic Injury Surveillance System.²⁰ As table 3 reports, an estimated 266 000 fire survivors were injured, of whom 14 100 were admitted to hospitals.

(6) WHAT DO RESIDENTIAL FIRES AND FIRE INJURIES COST?

Savings in fire costs are the potential benefits from the intervention. The estimated cost per residential fire burn victim (table 3) is based on a model developed in a report to Congress on cigarette fire costs.²⁰ Non-hospital medical costs were based on the 1987 National Medical Expenditure Survey (NMES) and third party payer data. Hospital costs used NMES data and Worker's Compensation payments data. NHDS data from 1984-90 on length of stay were used to estimate costs by body part burned and degree of burn. Costs for injuries other than burns and anoxia are from the databook on non-fatal injury.²¹

To assess how burn and anoxia costs vary by cause, we used 1990 hospital discharge data from California, where causes are coded for more than 90% of injuries. We also used data from burn centers, where more detailed causes are recorded. Serious cases are triaged to burn centers; the data cover all centers serving Delaware, New Jersey, and the eastern half of Pennsylvania, and represent about 40% of burn hospitalizations in that area.

Wage and housework losses were modeled using National Health Interview Survey data.

A total of 397 jury verdicts were used to value pain, suffering, and lost quality of life associated with burns by cause and severity. Property damage and loss are based on national fire statistics.

Estimated total annual residential fire losses are \$34.3 billion (in 1994 dollars). This includes \$0.7 billion for medical care, \$5.5 billion for other tangible injury costs, \$22.0 billion for pain and suffering, and \$6.1 billion for property damage (table 4).

(7) HOW EFFECTIVE ARE SMOKE DETECTORS?

Using time series analysis, Garbacz estimated smoke detector effectiveness against residential fire burn deaths to be 15.5%.²² We assume detectors reduced non-fatal injuries proportionally. Garbacz's estimate attributes most of the precipitous decline in fire deaths after the introduction of smoke detectors to other factors and is, therefore, conservative. In contrast, National Bureau of Standards (NBS) engineering estimates suggest detectors are 45% effective against deaths and 30% effective against non-fatal injuries.²³ This is close to Hall's estimate of roughly 50% effectiveness against fatalities.²⁴

The odds of a residential fatality in a home without smoke detectors is 10.5 times the odds with detectors.¹⁶ This implies 90% effectiveness, but fails to control for any factors that make homes without detectors more fire prone. We computed benefit cost ratios using both the Garbacz²² and NBS²³ estimates, and assessed the added savings assuming detectors were 10% effective against property damage.

Table 3 Costs per fire injury by diagnosis group and level of treatment (in 1994 dollars)

	No of cases	Medical/EMS*	Work	Legal/admistration	Pain and suffering	Total
Burn						
Fatal	4 120	12 840	727 496	24 750	2 011 378	2 776 464
Hospital	11 677	42 842	45 689	17 302	707 041	812 874
Emergency department	151 470	798	3 354	58	13 166	17 376
Other	61 623	110	456	8	1 818	2 392
Anoxia						
Fatal	1 058	12 425	727 496	24 719	2 011 378	2 776 018
Hospital	1 276	5 170	16 868	3 324	120 068	145 430
Emergency department	14 398	802	3 324	65	13 269	17 460
Other	3 006	115	456	9	1 891	2 471
Other injury						
Fatal	136	12 818	727 496	24 742	2 011 378	2 776 434
Hospital	1 181	14 904	34 092	6 585	251 060	306 641
Emergency department/other	6 192	638	1 281	55	11 879	13 853
Firefighter injury						
Fatal	3	13 496	1 026 881	30 679	1 834 852	2 905 908
Non-fatal	14 820	1 252	3 847	1 752	22 810	29 661

*EMS=emergency medical services.

Table 4 Annual injury costs (in millions of 1994 dollars)

	No of cases	Medical/EMS	Work	Legal/admistration	Pain and suffering	Total
Fatal	5 317	68	3 869	132	10 694	14 763
Non-fatal	265 643	680	1 246	250	11 332	13 508
Total	270 960	748	5 115	382	22 026	28 271

(8) HOW MANY DEATHS AND INJURIES CAN SMOKE DETECTORS PREVENT?

Incidence data were from a time when about 88% of homes had smoke detectors.¹⁶ A national survey with professional operability testing found 81.2% of the homes with smoke detectors had at least one operational unit.¹⁶ This means 71.4% of all homes have at least one working detector. To compute losses for homes without any smoke detectors, we divide 1991 losses by the fraction of losses not averted at the 71.4% usage rate (1-0.714 with working detectors x average effectiveness).

From the Garbacz²² effectiveness estimates, without detectors the annual fire toll would be \$31.8 billion (\$0.8 billion in medical costs, \$6.2 billion in other tangible costs, and \$24.8 billion in lost quality of life). From the NBS²³ effectiveness estimates and computing fatal and non-fatal costs separately, the annual toll would be \$38.9 billion (\$0.9 billion in medical costs, \$7.8 billion in other tangible costs, and \$30.2 billion in lost quality of life). Assuming detectors reduce also property losses, property losses would total \$6.5 billion.

(9) WHAT NET COST SAVINGS, TOTAL AND PER HOME DETECTOR, RESULT FROM SMOKE DETECTOR USE?

Universal detector installation, assuming 81.2% are operational, would reduce the annual cost by \$4 billion,²² or by \$12 billion.²³ If all detectors were operational, another \$1.0–2.9 billion would be saved. Property damage reductions add \$0.5 billion to the savings.

Thus, the estimated cost savings per detector are \$210–636. This includes \$6–13 in medical spending, \$41–137 in other tangible costs, and quality of life gains valued at \$163–486. (The total excludes \$28 in possible property damage savings.) Thus, the benefit cost ratio for a detector is 5.5–15.5 (210/42.90 to 636/42.90). Ignoring time costs and quality of life benefits but including property damage, the ratio of tangible benefits to out-of-pocket costs is 3.0–7.5 (74/23.60 to 178/23.60).

(10) WHAT UNCOSTED OUTCOMES RESULT?

- Parents will spend less time and expense caring for injured children.
- Lawyers will file fewer lawsuits seeking compensation for fire injuries.
- Some smoke detectors will trigger unnecessarily (for example, when an attended frying pan smokes).
- Pets will be saved from death and injury.

(11) HOW WILL INSURANCE PAYMENTS CHANGE?

Insurers, public and private, will save almost all of the medical payments, claims processing expenses, and legal expenses, an estimated \$8–21 per detector. If property damage is reduced, home insurance claims may drop by an additional \$25 per detector, or \$45 per home.

(12) HOW SENSITIVE ARE THE RESULTS?

The estimated return is sensitive to the detector's effectiveness, the per cent of installed detectors that are operating, and the discount rate. Even at the most conservative effectiveness level, however, the tangible returns alone are several times the costs.

Discussion

Some of the basic problems encountered in trying to understand and interpret cost outcome analyses arise because the perspective of the analysis, the intervention being analyzed, the target population, the time horizon, or assumptions used in developing any models, have not been clearly defined. For example, the only data on outcomes may be from a trauma center/registry, rarely a representative source. Registries ignore the effects of cases in other settings; for example, less severe burns may increase in other hospitals as severe burn victims in burn centers covered by the registry are reduced.

In analyzing the costs of an intervention,

certain costs may be omitted. These include overhead costs for offices and administration, fringe payments for labor, volunteer time, and maintenance on machines. Other problems are more mundane, such as the failure to discount benefits or costs that arise in different years.

When determining medical care costs or savings, charges are sometimes not distinguished from actual payments. For most US medical claims, the costs are negotiated and differ considerably from the listed charges. If that is the case, it should be made explicit, and a discussion should follow on whether future costs also will depend upon negotiations.

The size of benefits may also depend on the way data are collected. For example, police world wide have datasets on assault and rape cases. Counts from such datasets understate incidence because many crimes are not reported to the police. Highway crashes also are under-reported; and injured victims are under-counted or misclassified in reported crashes (because the officer does not examine the victim). In the US, alcohol use is not identified in police reports for one third to one half of drunk driving crashes involving a non-fatal injury, while police reports tend to overestimate belt use.²⁵

The list of benefits may be too narrow. Omitting non-medical or quality of life outcomes cheats the program of its rightful credit. In particular, work and quality of life gains often make up a large portion of benefits from a social perspective. From a government perspective, transfer payments may be important.

The extent of benefits may also be understated because the analysis is limited to short term effects. For example, parent counseling with the American Academy of Pediatrics TIPP program for a firstborn may lead to changes in parent safety practices for a second child without further counseling.²⁶ On the other hand, prospective analysis may fail to consider implementation delays or failure to implement. The benefits estimate also may be exaggerated by failure to adjust for non-use or misuse. An unbuckled child safety seat or a smoke detector with a dead battery offers no protection.

Care is needed in reporting and interpreting cost outcome results. Suppose our CBA of smoke detectors stressed the dollars saved per dollar invested rather than per detector purchased. This approach could mislead those detector distribution programs that were paying more (or less) for their detector than the price in our analysis.

To compare cost outcome results in the *same* unit of effectiveness, analysts must be aware that factors such as population characteristics, the scale of the intervention, and the presence of other programs could influence the results. For example, gender, age, ethnicity, environmental conditions, or condition specific risk factors may predispose people to a particular problem. Consequently, the costs, as well as the effectiveness, of the intervention will vary across populations, creating differences in cost outcome ratios. If possible, those evaluating an intervention that serves groups of people with

different characteristics should calculate *population specific cost outcome ratios* in addition to a total ratio. In addition, the analysis could depend on the scale of the intervention. For example, a small program that saves one life could have a higher cost effectiveness ratio than a large program that saves many. In developing a comprehensive safety approach, it is also critical to understand how interventions interact. For example, the effectiveness of a sobriety checkpoint program will be reduced if vigorous enforcement of laws against sales to minors reduces the number of drunk drivers on the road.

When evaluating alternatives in a resource constrained world, the highest benefit cost ratio is not necessarily the best choice. An alternative may yield larger total benefits but at a slightly higher cost per unit of safety. When evaluating related alternatives, the incremental, rather than total cost and benefit, should be evaluated. The benefits of provisional licensing of youth with a curfew at 10 pm may exceed its costs, but the benefits of a 10 pm curfew relative to a 12 pm curfew are smaller than the incremented costs.¹¹

Conclusion

Cost outcome analysis is often used to justify a particular program to government decision makers, or to managed care providers. Perhaps more important is its value in guiding choices among alternative interventions in a resource constrained world. To compare programs or base decisions on cost outcome analysis for a particular program, cost outcome analyses need to maintain a high level of quality.^{16 7 10} The inclusion of a common perspective, such as the societal perspective, and common cost categories in all analyses, facilitates comparison between interventions.

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Burns due to head lice treatment

Dr el Habashy, a senior house officer in the burns unit at Selly Oak Hospital, Birmingham, reported that a 7 year old girl came to the unit with burns to her face covering 3% of her total body surface area. She had been treated with malathion (Prioderm) for her hair lice. The fumes from the lotion made her panic, and as she ran past the lit gas cooker at a distance of 1 m a trail of fire followed her and caused severe burns. Prioderm contains isopropyl alcohol and should be applied in a well ventilated room well away from any naked flames (*BMJ* 19 July 1997, p 198).