Cost Benefit Analysis of Industrial Noise Regulation

Stephen Holland* and Jean Cross**

Abstract

This paper examines the application of the techniques of economic analysis to occupational health and safety regulations using occupational noise as an example.

The paper explores the extent to which economic impact studies are practically feasible and useful in relation to occupational health and safety legislation. Six studies of the same regulatory change, from four countries were analysed. The results of these studies ranged from a strongly negative to a significantly positive net present value, depending on the assumptions made. The factor which had the greatest influence on these differences was the way in which benefits are costed.

It is shown that in the field of Occupational Health and Safety, economic analysis does not produce a single valid net present value or benefit to cost ratio on which a decision to legislate can sensibly be based. However the analysis can, if properly directed provide useful information on factors which will enable organisations to optimise their response to the regulation and authorities to introduce regulations in a way which does not bear with unreasonable weight on specific sectors of the community.

* Worksafe Australia. The views expressed in this paper are those of the authors and do not necessarily reflect those of the National Occupational Health and Safety Commission (Worksafe Australia).

** Department Safety Science, The University of New South Wales.

Introduction

In many countries industry perceives that it is over regulated by Government. Governments have responded by requiring an economic analysis to be carried out as one part of the legislative decision making process. In 1985 the UK Government published a white paper called 'Lifting the Burdens of Government'. This requires all Departments developing proposals for regulatory control to underpin and to some extent to justify them with a structured assessment of the likely economic impact, particularly on businesses. In Denmark the Directorate of Labour Inspection is required to undertake economic appraisals prior to the promulgation of any new standard for the workplace. In Canada the Canadian Labour Code requires any amendment to existing legislation to be accompanied by an analysis of the anticipated economic impact of the amendment. In Australia an economic cost benefit analysis forms part of a mandatory Regulatory Impact Statement in two States (Victoria and New South Wales).

In the United States the Occupational Health and Safety Act does not specify how economic considerations are to be balanced but states that a standard should be set so that it '*most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee shall suffer material impairment of health or functional capacity*'.

The definition of 'to the extent feasible', in economic terms is undefined and it is argued that formal cost benefit analysis is unsuited to the assessment of Occupational Health and Safety Standards. This view is also held by Lindeneg (1985) who looked at the theoretical basis of economic analysis and concluded:

> There is no objective way of calculating the economic costs to Society, ie the net value of gains and drawbacks associated with a new standard for the working environment.

One particular piece of legislation which has been analysed in several studies across the world is the reduction of the noise limit from to 90dB(A) to 85dB(A). It has been estimated that if the noise limit is 85dB (A) for an 8 hour day approximately 8% of the exposed population will suffer hearing loss of 25dB or more after prolonged exposure. With the noise level limit set at the present standard of 90dB(A) the percentage rises to 18%. Noise levels in the 95–100dB (A) range which are still commonly found in industry cause hearing loss in 28–40% of the exposed population (Miller 1976).

It has been argued by some industries that it is not feasible to reduce noise at source to 85dB(A) and by others that it is prohibitively expensive. This regulation was therefore an obvious candidate for economic analysis.

Methodologies of Economic Analysis of Safety Issues

There are four methodologies of economic analysis commonly used when considering safety issues,

Financial Appraisal

The simplest is a financial evaluation which takes account only of entities that appear in an organisations accounts. In the case of the noise regulation, the cost of compliance could be equipment modification, enclosure of noisy equipment, personal protective equipment and training in its use. The benefits of the regulation are a reduction in workers compensation claims. As pointed out by Lindeneg (1985) the purpose of regulation is seldom to improve profits and an analysis of costs and benefits which does not include the real purpose of the legislation in some way is theoretically flawed.

Cost Benefit Analysis

Societal cost benefit analysis offers a means of bringing intangible benefits into a logical economic analysis. It is assumed that the objective is to maximise social welfare and that all costs and benefits can be expressed in monetary terms. All gains and losses experienced by society as a whole, individuals and agencies within society are identified. A financial value is assigned to each gain and loss, both tangible and intangible, and the aggregate gain or loss resulting from the regulation is calculated. If there is a net gain then the regulation is beneficial.

Cost Effectiveness

In a cost effectiveness analysis all gains and losses are considered but not all have to be translated into money. For example, the extent of deafness and its social and economic effects in different sectors would be discussed but not necessarily translated to monetary terms. The monetary costs of achieving a range of benefits would then be calculated. Cost effectiveness analysis is particularly useful when several different means of achieving the same benefit are being compared.

Cost of Illness Studies

An empirical tradition has built up in the health and safety profession from the need to evaluate the full costs of poor health and safety to industry. The methodology attempts to assign a value to the hidden costs of accident, injury and disease which impinge on an organisations finances. Thus in the case of an accident not only the insured costs (Workers compensation, public/third party liability, property damage etc) are included but also uninsured costs (product, material and equipment damage, legal costs, production delays, overtime working, lost time and the time of all involved in the follow up to the accident). It has been customary in these studies to quote a ratio of insured to uninsured costs. Values in the literature for the ratio insured: uninsured range from 0.5:1 to 1:36 (eg HSE 1993, Levitt et al 1981, Leopold and Leonard 1987, Andreoni 1986).

The Studies

All the studies discussed in this paper attempted a cost benefit analysis.

Noise exposure of workers can be reduced by purchase of new quieter machinery, by modifying the design of existing machinery, by enclosing the machinery in a sound proof enclosure, by providing a sound proof work area for the employee, by providing ear muffs or other personal protective equipment backed up by regular audiometry testing or by job rotation to reduce exposure time. Costing can assume that new machinery is purchased immediately or as machinery comes up for replacement in the ordinary course of events. Each option for compliance will have different costs.

The purpose of a lower noise level is to reduce industrial deafness which in some industries is currently the most prevalent industrial disease (Australian Bureau of Statistics 1993). The direct benefit of reduced deafness to the employer is reduced compensation claims and reduced costs of claim management. There are a number of other problems which have been associated with noise that would be reduced by a reduced regulatory limit. These include industrial accidents, sickness absences, high blood pressure, anxiety, irritability and reproductive problems in women. Noise has also been shown to affect the efficiency of performance of some types of task particularly those requiring focussed mental effort (Smith 1991, Umemura, Honda and Kikuchi 1992).

The benefits to the worker include improved quality of life through the ability to hear sounds and music and communicate easily with family and friends. Benefits to the community include a reduction of the social problems of deaf people and reduced costs of social and health care for deaf people, particularly the elderly, many of whom acquired their hearing loss at work.

The Time Value of Money

The general principle in economic analysis that money in the hand now is worth more than money gained in the future, based on the potential earning power of present cash, is problematic when the gains are long term. The discounting rate compounds over a large number of years so a life saved in the future is worth significantly less than a life saved now. Thus a very low present value is attached to reducing cancers which only manifest themselves in 20–30 years time. Deafness is often induced gradually over 40 years and the benefit of reducing deafness will also tend to have a low present value.

One theoretical way round this problem is to value long term benefits by finding what someone would be willing to pay now to avoid deafness (or cancer) in the future. This path was not taken in any of the studies compared here but is theoretically valid and might be expected to lead to quite different results than the studies that are reported here. The different studies chose different discounting rates as shown in summary in Table 1.

Table 1

	BBN USA 1976	HSE 1988	Canada 1990
Noise Monitoring /empl/pa	A$31 US$12	$72.50	$92.40
Noise Control /empl/pa	A$1615 US$615	$1865	$1073
PPE / exposed empl /pa	A$26 US$10	$56	$80.96
Audiometry/ exp empl/pa	A$52 US$20		
Basis of benefits calculation	0.2% all production workers x av claim	70% 1981 claims	60% 1988 claims
Total costs all industry (NPV)	US$8billion (1976)	$855 –$1168m	$29.6m
Benefits (NPV) compensation	US$16million	$392–$552m	$42.7m
Benefits other	Nil	Nil	Nil
Benefits / exposed person	A$9.3 US $3.5	$920	$1802
Benefits/costs	1/500	1/3–1/1.3	1.4/1
Costs – Benefits	$8 billion cost	$739–303m cost	$13.1m benefit
Discount	7% over 45 yrs		13% over 10 yrs

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BBN USA

In 1973 the Occupational Health and Safety Administration (OSHA) commissioned Bolt, Beranek and Newman Inc (BBN) to estimate the cost of compliance with the existing 90dB noise level and to make estimates for compliance with a regulation which introduced an 85dB limit and a requirement for audiometric testing.

Over a period of 3 years BBN visited 68 industrial plants representing 19 industries and prepared estimates of costs of compliance with each standard based on information received from the companies. The cost of compliance was primarily for retrofit of noise control to existing machinery. In each of the 68 plants the difference between the costs of compliance with an 85dB and a 90dB standard were calculated. The sum was divided by the number of production workers employed in that plant then multiplied by the total number of production workers in industry to obtain an industry figure.

The benefit was estimated to be the savings in workers compensation payments as a result of the reduced incidence of industrial deafness. BBN estimated that the differential number of workers protected from hearing loss by a change from 90dB to 85dB was 0.2% of all production workers. This was multiplied by the average claim (US$531, 1976) to obtain the total benefit.

HSE UK

In 1988 the Health and Safety Executive in the UK used desk top estimations rather than case studies to estimate the cost of compliance. The benefits were again taken as a reduction in workers compensation for hearing loss claims, but the figure was calculated as a percentage improvement on existing claims. It was recognised that this substantially undervalues the benefits and other benefits were discussed but not quantified. A small benefit was included which represented savings to the community for the provision of free hearing aids by the National Health Service. (This was only a few percent of the workers compensation savings). In the UK the introduction of an 85dB level was to be accompanied by a requirement for formal workplace noise assessment.

Canada

A Canadian study was carried out in 1990 as part of a regulatory impact statement on a proposal to reduce the noise regulatory limit from 90dB to 87dB. The study used desk top estimates and interviews to assess noise levels. The Canadian study used the USA figures from the BBN study for the cost of noise reduction at source but estimated a lower cost per person as a result of assumptions made about differences in industry type between the USA and Canada.

The benefits listed included tax advantages, improved morale and worker performance reduced accidents, absenteeism and staff turnover and reduced litigation costs. However, only workers compensation reductions were quantified. Five percent of the average annual medical aid and capitalised pension costs for Canada were estimated to be industrial noise related. This sum was divided by the number of claims to get a cost per claim. This was then multiplied by the expected number of people to suffer hearing loss at 85 and 90dB. This figure was calculated assuming 60% of the existing number of claims would disappear.

Comparison of UK, USA and Canadian Studies

The results of the three studies are compared in Table 1. The figures have been translated to Australian 1991 dollars to allow cross comparison using the 1991 exchange rate and an inflation rate of 4% per annum. The USA figures quoted in the Canadian study were used as these had been adjusted from US 1976 figures to Canadian 1988 figures using the actual price index comparison for each year. The original US figures are also shown. The differences in workforce size is considered by expressing some costs and benefits averaged over the number of employees. Following the practice of the original studies audiometry and personal protective equipment costs are expressed per noise exposed person and the capital costs per production worker.

Noise monitoring, audiometry and personal protective equipment are annual costs whereas the noise control cost is a once off in the first year. In all three studies the costs were taken to include the costs of noise reduction by engineering controls (equipment modification and enclosure) and the use of personal protection.

None of the studies included a cost to Government for enforcement of the standard, as this was considered to be unchanged from enforcement costs of the existing standard.

In 1973 BBN estimated the equipment modification cost to be US$18 billion. This was subsequently reduced to US$8 billion as a result of better data that came to light as the study progressed and experience of actual expenditures and industry practices were obtained (Bruce et al 1976).

The assumptions made in the original study appeared very reasonable and were only found to be inaccurate as a result of three years of visits to the plant. Desk top studies where many assumptions must be made about the workplace are liable to this degree of inaccuracy.

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The Canadian and British studies are very similar in methodology. They choose the same way of quantifying benefits and derive costs from the USA BBN study. The Canadian study ends with a small benefit and the UK study with a small cost. This results from assumptions made about exposure numbers and industry profiles for the two countries. The UK estimates for cost of control/person is 1.7 times the Canadian estimate again this is because of the different industry profiles assumed.

There are two significant reasons why the USA study results in a very low benefit to cost ratio compared to Canada and the UK. In the USA study the total reduction in the number of claims is estimated as 0.2% of 1976 production workers (This is 0.66% of exposed workers or 30,000 people). The other two studies estimate a percentage reduction of existing claims and assume that this will continue each year for the total time period of the study (For example in the Canadian study the number of claims per year is assumed to reduce by 60%). This works out to be 0.35% of exposed population. The gain is assumed to occur annually for 10 years. There is also a significant difference in the size of the claim. The average claim in the USA is US$531 1976 (Equivalent to A$1381 1991). The average claim in Canada is equivalent to A$6000.

Australian Studies

Gibson and Norton

In 1981 Gibson and Norton estimated the cost of meeting the existing 90dB standard. They again used the BBN survey to estimate costs of compliance adjusting to Australian industry using figures from the Australian Bureau of Statistics and consultants. No adjustment was made for the time value of money. The analysis was carried out in terms of the total cost of reduced noise and hearing protection per employee and the average compensation claim per employee.

Victorian Study

The Victorian study was commissioned by the Occupational Health and Safety Authority in Victoria as part of a regulatory impact statement for a proposal to introduce a 5dB reduction in the noise limit over a staged period of time.

The cost of engineering controls for noise reduction was estimated from SHARE (Safety and Health Accumulated Research and Experience). This program collects successful solutions to common occupational health and safety problems. In 1991 there were 59 noise control solutions in the

SHARE program. Using this data, the Victorian study estimated a cost of $100/dB per person. However the analysis omitted the solutions where enclosures were fitted. A re-analysis of the SHARE data has been carried out by Holland (1992) based on information from Else (1990). The average cost of Engineering control increased to $168 per dB reduction per person.

The Victorian study took a cost of illness approach to non compensation benefits with a ratio of 4:1 for uninsured to insured costs of deafness. This was justified as a compromise to the range of ratios between 1:1 and 7:1 quoted by Andreoni (1986) and the Australian Ministerial OHS Review (1990).

BIE Study

Worksafe Australia commissioned the Bureau of Industry Economics to carry out a case study demonstration covering two high risk industries. (Fabricated Metals FM and Base Metals BM). Personal interviews were held over a period of three months with workplace occupational health and safety personnel, managers, safety engineers, health and safety committees and union delegates.

Table 2 Costs of Compliance with an 85dB Noise Limit (BIE Study)

COSTS	FINDINGS	VALUE /exp pers
Audiometric assessment	Also required for 90dB regulation	Zero
Personal protection	50% earplugs 50% muffs	$60
Training/ Information	Assumed present for 90dB	Zero
Investment in quiet machinery/ person	3% Capital expenditure	$2800
Machinery adaptation	6% Capital expenditure	$3273
Machinery enclosure	$10,000 per enclosure	$1000–$3300
Decreased efficiency because of enclosure	Unquantifiable	Zero
Increased maintenance	Unquantifiable	Zero
Operator enclosure	$30,000 per enclosure	
Noise assessments	Same as for 90dB regulation	Zero
Enforcement costs	Same as for 90dB regulation	Zero
Staff rotation	Same as for 90dB regulation	Zero

Tables 2 and 3 shows the potential costs and benefits considered. A sum equal to workers compensation costs is included for all indirect costs associated with deafness including claims processing costs and intangibles.

The study separately considered the full range of noise control methods including machine and operator enclosures, investment in new plant, machinery adaptation and redesign as well as the provision of protective equipment. The net present value of each solution was calculated.

Table 3 Benefits

BENEFITS		VALUE/exposed pers
Workers compensation	70% of current payments	\$77 (FM) \$184 (BM)
Absenteeism/ staff turnover	Estimated as 1 day per annum[6]	\$107 (FM)[7] \$130 (BM)
Increased productivity		Not quantified
Lower community health costs		*Not quantified*
Fewer secondary costs (eg traffic accidents)		Not quantified
Other Intangibles	Equal to benefits from reduced workers compensation[8]	\$77 (FM) \$184 (BM)
Latent Compensation Payments		Not quantified

The BIE study looked at 270 scenarios in all using discount rates of 5, 10 and 15% and a variety of options which might be taken by companies to comply with the regulation. The scenarios also looked at different times over which compliance might be phased in Table 4 shows a comparison of the Australian studies.

Table 4 Australian Studies

Study	Gibson & Norton	Victoria 1991	BIE[9]
Noise assessments	N/A	$82.50	0[10]
Noise Control/pers	$908[11]	$825	$1000–$7700
PPE	N/A	$44[12]	$90
Administration	N/A	$1000[13]	
Audiometry	N/A		$50–$60
Total costs all industry	$380m	$223m	+$32m-$361m[14]
Benefits compensation	$200m	$1076m (total)	$1.3m pa (FM) total $30.4m[13]
Benefits/ exp person			
Benefits/costs	1/2	5/1	
Costs – Benefits	$180m (costs)	$1053m (benefit)	
Discounting	None	5.36% over 15 yrs	5, 10 & 15% 15 yrs

Comparison of All Studies

The USA Canadian, UK and Gibson and Norton studies adopted the same basic approach, taking data for costs of compliance from the BBN study. Apart from the very low benefit in the American study discussed above, the outcomes were relatively close.

The other two Australian studies were broader in their methodologies and produced much more wide ranging results.

Estimating compliance costs

Considering all means of compliance there is a factor of nearly 5 to 1 in compliance costs in the studies. The highest estimate assumes that compliance is achieved by immediate replacement of machinery to 3% of total capital investment. It is clearly unlikely that industry would choose this solution. The lowest estimate of $840/exposed person, from the Victorian study is optimistic because solutions which are perceived to be particularly neat or cost effective are most likely to be those reported in SHARE. When like paths to compliance are compared the estimates of the costs fall within about a factor of 2 to 1 of each other. The differences are then mainly a function of the assumptions made about the number of exposed workers affected by an individual piece of equipment.

The Bureau of Economics study demonstrates the wide range of net present values for the case study industries (ranging from -$1034m to +$43m) depending on the path chosen to achieve compliance with the regulation and the time scale over which compliance is phased in.

The largest positive net present value was $43 million. This was obtained by taking the path of replacing noisy machinery with quiet machinery at its normal replacement time. A 5% discount rate was taken and it was assumed that the noisy machinery was 2% of total investment. Replacement of 2% of machinery over a 5 year period also produced a positive net present value for a 5% discount rate.

The most expensive options, which in cases exceeded -$500 million, was immediate replacement of noisy machinery where this represents up to 15% of the total investment.

The use of personal protective equipment to meet the regulation had a small positive net present value but was not one of the most cost effective solutions.

The most cost effective solution, phasing in the purchase of new quieter equipment over a long time scale of the life of equipment (or 10-15 years), was not considered in the UK, USA and Canadian studies.

A large number of assumptions must be made to adapt the very small sample from case studies to a very wide range of industry for a whole country (BBN found a variation of costs of compliance between $18 and $8 million when desk top estimates were changed in response to actual findings in industry).

In calculating a cost per employee all studies used the number of people currently exposed as the basis. No allowance was made for new people moving into the industry over the time for which benefits would accrue.

Estimates of Benefits

All studies used workers compensation to assess benefits. There was a factor of 10 to 1 difference in the estimates depending on whether benefits were estimated from existing annual claims or from expected hearing loss in people currently exposed to between 85 and 90dB. There was also a difference of 2 to 1 depending on whether benefits were calculated from compensation payments to workers or compensation costs which include insurance company overheads.

It would also be valid to calculate compensation benefits to industry from the workers compensation premium reduction due to reduced claims. This is likely to be minimal since a companies premium is usually dominated by injuries rather than deafness. All of the studies noted benefits for which no financial allowance was made.

In a full societal cost benefit analysis, financial values should be placed on all the variables discussed below. There is insufficient data available to do this in practice but the data demonstrates that these benefits could easily add up to a sum which is at least ten times the workers compensation costs on which most of the present studies are based.

The benefits suggested in the studies but not costed include:

- ## *Health Costs Borne by the Community*

In Australia pensioners who obtain free hearing aids and audiological services through Government programs cost the community $29 million in 1989 (This compares with a workers compensation cost of industrial deafness for one year of $35 million). The percentage of these who would not need hearing support if the level was reduced from 90–85dB is not known. There will also be non pensioners who receive medical attention for hearing related disorders through Medicare, the government national health insurance system.

In Victoria 1200 people are admitted to hospital with hearing disorders each year with an average stay of 3 days. Again it is not possible to estimate how much is attributable to the workplace. Laboratory studies have shown increased heart rate blood pressure and body temperature in people exposed to 90dB (Bhattacharya et al 1991). However most measurements in workers exposed to noisy conditions have not confirmed these results and it is believed that people may adapt physically to prolonged exposure (eg Hirai et al 1991). There appear to be some differences in the association of hypertension with noise with gender and race (Tarter and Robins 1990, Zhao et al 1991, Lang, Fouriaud and Jacquinet-Salord).

A Chinese study of 978 women and 402 controls found that women exposed to noise showed a significantly increased rate for irregular menstrual cycles hypertension in pregnancy, lumbago, spontaneous abortion, premature labour and low birth weights of new borns. A dose response relationship between incidence rates and noise level was evident (Zhan et al 1991). Laboratory animals show changes to the immune system but this has not been confirmed or refuted in man.

It is not possible to cost the benefits resulting from a reduction in possible health effects outlined above since noise is just one of the factors associated with the ill health outcomes concerned. Also the cost is borne by the community health system where individual types of problem are not separately costed. However these costs are not necessarily negligible.

■ *Quality of life*

The individual loses quality of life because of difficulties in communicating and inability to take pleasure in sounds. Communication difficulties lead to frustration and stress in both the individual and family and friends. It is difficult to assign a dollar value to this but it would be possible to use a willingness to pay approach. This is an important omission as it is presumably the main motivation for the legislation.

■ *Litigation*

Litigation costs for fighting claims are not included in any study. The only figures given state that in Ontario in 1987 the workers compensation board processed $12m of claims and spent $1m fighting claims made by the local branch of the United Steel Workers of America alone.

■ *Potential claims*

Small scale studies in individual companies indicate that the number of potential claims is very much greater than the number of actual claims. No substantiated evidence is published but private communications indicate that up to about 50% of an exposed population show evidence of hearing loss whereas present claims represent about 0.5% of the exposed population. This demonstrates the significant size of the potential claims and the dangers of basing estimates of future benefits on current claims data.

■ *Tax advantages*

None of the studies included tax considerations. In most countries the cost of equipment modifications is tax deductable (39% in Australia). There is also an accelerated depreciation allowance for obsolete equipment.

■ *Increased productivity*

Noise has been demonstrated to slow performance and increase error rates in both laboratory and field studies (eg. Levy-Leboyer and Moser 1988).

There is evidence that performance of some types of task deteriorates at high noise levels. Mental tasks and tasks requiring focussed attention are most adversely affected. (Smith 1991). Visual acuity and near point accommodation are also affected by noise (Harazin Grzesik, Pawlas and Kozak).

The BIE study identified the most economically beneficially route to compliance to be replacement of machinery with a significant phasing in period. However the BIE study did not include a value for the probable increased productivity from more modern and efficient machinery. Anecdotal evidence indicates that this is often the greatest financial benefit gained from the introduction of new equipment which could far outweigh the benefits from reduced compensation for deafness.

Faster introduction of new machinery may improve competitiveness (on the other hand investment in quiet machinery might divert resources from other new equipment). Noise is often a by product of wear or tool and material vibration and energy dissipation. Eliminating noise can result in enhanced quality and longer equipment life. Good quality productive employees are less likely to stay in a company where conditions are poor. Noise is one of those conditions.

■ *Administrative costs*

Only the Victorian study included a component to account for administration costs and claims management time.

■ *Present compliance*

The studies all assume present compliance with the existing 90dB limit. In fact in most countries this regulation is very poorly adhered to and there are very high levels of noise and hearing loss in industry. The incremental cost of replacing new equipment and adapting old equipment currently above 90dB to reach 85dB may not be large. Hence the cost to industry of introducing an 85dB level might not be much greater than the cost of enforcing the existing legislative limit. In practice an 85dB legislative limit might bring average noise levels down in very noisy environments rather than reduce noise levels from 90dB to 85dB. This would tend to have a greater effect on the incidence of deafness than is assumed in the studies as noise is measured on a logarithmic scale.

■ *Reduced accidents*

There have been several studies relating accident rates to noisy environments. Cohen (1976) showed accident rates can be up to 20 times as high in a noisy environment.

In a case controlled study of the risk of injuries to shipyard workers in the Netherlands the three factors found to be most highly associated with injuries were alcohol consumption, hearing loss greater than 20dB and noise levels higher than 82dB. In this study, which focussed on factors which could interfere with the faculties required for recognising warning signals, risks attributable to noise and hearing loss together accounted for 43% of injuries. (Moll-van Charante and Mulder 1990). High noise levels have been associated with balance disfunction which also has the potential to lead to accidents (Kilburn, Warshaw and Hanscom 1992).

Melamud Luz and Green (1992) found a significant increase in accident rates and sickness absences in both male and female workers at higher noise exposures (85dB). The effects were particularly strong and occurred at more moderate noise levels if the workers reported being annoyed by noise. Men also reported higher levels of job dissatisfaction and irritability. Women had increased anxiety and depression. This study indicates that adverse affects may occur at lower noise levels than those which result in hearing loss.

Since workers compensation claims for deafness are usually only of the order of 10% those for accidents even a very moderate decrease in the accident rate makes a significant addition to the workers compensation gain if noise levels were to be reduced. Although this represents significant evidence that hearing loss is only one of the problems that would be reduced by a lower noise limit. The additional factors are extremely hard to cost and will vary from organisation to organisation. Benefits from reducing these problems could significantly exceed workers compensation claims which is the only factor used to calculate benefits in all the studies.

Dollar values were not placed on any of the benefits outlined above because any value chosen is very hard to justify. However since all the omissions from the studies are benefits a distorted view is obtained if they are omitted. Table 5 shows estimated values for some of the benefits of noise reduction taken from a Worksafe cost of illness study on noise (National Occupational Health and Safety Commission 1991).

Table 5 Estimates of Annual Losses due to Noise in Australia, 1991

Source of Loss	Annual loss per noise exposed employee
Workers compensation	$130
Absenteeism[15]	$570
Staff turnover	$100
Employee quality	$330
Productivity[16]	$660
TOTAL	$1790

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Other Variations in Assumptions

The studies used different discounting rates and different time periods to take account of the time value of money. Some studies chose to carry out the analysis over the time scale over which deafness develops (up to 45 years) others chose a period of 10 years which represents the lifetime of equipment and machinery.

Table 6 demonstrates the relative influence of varying some of the assumptions on the figures obtained in the Victorian study.

Table 6

Assumption	NPV
Original Victorian study	+ $468.6m
With cost of engineering controls for 5dB reduction $840 (rather than $500)	+ $416m
Using a Ratio of insured to uninsured costs of 1:1 instead of 1:4	+ $184.5m
Using a discount rate 8% (instead of 5%)	+ $322m
Costing hearing protection @ $32 per employee instead of $20	+ $444.5m
All of above assumptions	+ $45m

Summary

Economic analysis of a regulation can produce a very wide range of results including both positive and negative net present values depending on the assumptions made in the analysis. The studies evaluated here demonstrated a wide variation in benefit to cost ratio and net present value, in spite of the fact that most had drawn on the original BBN study for both data and methodology. There is scope for an even wider range of outcome if other economically valid methodologies are chosen.

There are a large number of factors which have a financial impact but for which there is too little data to allow good quantification. As a result it is impossible to quantify benefits even to within an order of magnitude accuracy.

All studies agree that the use of workers compensation payments alone underestimates benefits. However all except the Victorian study also decided that obtaining a valid estimate of other costs was too hard. A case can be made that total benefits are at least 10 times workers compensation payments. More data needs to be obtained before a realistic estimate of benefits can be made.

Even where benefits are limited to a reduction in workers compensation, a large difference in benefit can be estimated depending on the assumptions made about the rate of future claims.

The BIE study demonstrates the sensitivity of the analysis to the model chosen for noise control. Net present values between +43m and –$1034 were obtained. This demonstrates that if an economic analysis is to be valid it needs to explore a wide range of routes to compliance.

The industry average for the net present value is obtained from individual case studies after many approximations. This also can affect net present values significantly particularly if the assumptions are made from a desk top analysis. BBN revised figures for cost of compliance down by more than a factor of 2 from the desk top estimates following site visits.

Cost benefit analysis has inherent problems when the cost must be paid immediately but the benefits accrue over a long time period. It cannot be justified morally that it is less acceptable to cause a disease that happens quickly than to cause a disease which has a delayed action yet this is the consequences of using standard discounting to evaluate benefits associated with disease reduction.

Variations in the choice of discount rate and time have a significant effect on outcome particularly in this case where the time over which benefits were considered to accrue varied between 10 and 45 years.

A major value of economic analysis, demonstrated most strongly by the Australian BIE study is that, it can be used to identify the most economically favourable route to compliance. In this case, the use of personal protective equipment was not found to be as beneficial as adaptation or replacement of equipment over a reasonably long time scale. Economic analysis, if appropriately, directed can identify specific circumstances under which certain sectors could be obliged to bear unacceptable costs. A requirement for immediate compliance of an 85dB level in an industry where there is a high capital investment in noisy equipment could make some organisations uneconomic.

Even with a very extensive analysis such as was carried out by BBN in the USA and BIE in Australia it is not possible to produce a single net present value on which regulatory decisions can be based. Economic analysis is a valuable part of the decision making process because of the issues raised rather than for the final result which has too great a degree of uncertainty to be the basis of a decision.

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Notes

1. Assessment included an annual assessment, as per the other studies, and a five yearly hazard investigation by an acoustical engineer.
2. Incudes training costs for UK and Canada – these are not mentioned in USA study.
3. Dominated by machinery adaptation costs.
4. This assumes immediate investment in quieter machinery. Averaged over population of exposed people including those presently exposed to over 90dB.
5. Based on Hocking and Savage 1989.
6. There was no real justification for this figure a US study in 1981 (Dept Labour 1981) estimated between 1.55 and 3.9 days lost per annum per worker for exposure over 90dB Worksafe Australia (1990) estimated four days for a noise exposed employee without stating the level of noise considered.
7. FM Fabricated metals BM Base metals.
8. With no real justification.
9. Total costs are for case study industries.
10. Noise assessment is a requirement for 90dB regulation so there is no additional cost when reducing the limit to 85dB.
11. All industry average, metals industry cost = $1694/person.
12. Including equipment, audiometry and training.
13. Based on a consultants estimate of $500 and subsequently doubled by Victorian Economists.
14. Taking 10% discount rate.
15. Taken from data which applies to higher noise levels than being considered here Noweir (1984).
16. Worksafe takes a figure which is lower than the lowest estimate of the field studies in suggesting a 2% productivity loss in a noisy environment as compared with a quiet one.

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