The Canadian Journal of Program Evaluation Special Issue 1997 Pages 83–97
ISSN 0834-1516

THE TREND SCENARIO METHOD IN COST-BENEFIT ANALYSIS: A MODEL FOR THE EVALUATION OF OCCUPATIONAL SAFETY AND HEALTH REGULATIONS

Alex G. Berljawsky
Labour Branch
Human Resources Development Canada
Hull, Quebec

Abstract: This article outlines the trend scenario method of analyzing costs and benefits in Canadian federal government occupational safety and health regulations. The trend scenario enables a comprehensive cost-benefit evaluation model involving past trends and parameter projections, which improve reliability of and control over the predicted results, as long as the assumptions and parameters are carefully documented and qualified. Inherent biases and limitations of this trend scenario method are also discussed.

Résumé: Cet article définie le scénario de tendance utilisé dans l'analyse des coûts et des avantages des règlements de santé et de sécurité au travail du gouvernement canadien. Le scénario de tendance permet d'établir un modèle d'évaluation coût-avantages complet impliquant des tendances passées et des projections de paramètre qui améliore le contrôle et la fiabilité des résultats estimés, à condition que les suppositions et les paramètres soient documentés avec soin et bien délimités. Les limites naturelles et partis pris concernant ce scénario de tendance sont discutés.

The Labour Program of Human Resources Development Canada (HRDC) develops occupational safety and health (OSH) regulations for industries within Canadian federal jurisdiction. This is done in accordance with the Canada Labour Code (Part II) and in consultation with labor and management. The Treasury Board of Canada requires that new or revised federal regulations result in a *net benefit for Canadians*. The publication of new or updated OSH regulations contains a formal statement of economic and social impact, based on a detailed analysis of the inherent costs and benefits. A new or revised regulation does not proceed unless the benefits exceed the costs, and according to Treasury Board policy, this must be documented in a formal analysis. In the case of OSH regulations, HRDC–Labour performs this statistical analysis with a model using the *trend scenario* as its method.

The origins of government intervention in workplace health and safety are found within the economic theory of supply and demand. Adam Smith (1776) first outlined this theory, explaining how supply and demand in labor markets made it possible to arrive at a wage reflecting the value of the work to the employer as well as satisfying the worker's assessment of the job (including exposure to health risk or whether the job was challenging). Smith further proposed that the highest possible level of workplace welfare could in theory come about by bargaining for wages to increase in proportion to the inherent danger of the work.

Today, this theory is elaborated in the particular context of implicit markets and shadow prices by Rosen's (1974) hedonic theory of prices. Based on the premise that human behavior is directed by the quest for pleasure, the hedonic principle evaluates goods and services in terms of their utility to the consumer. According to this method, rational self-interest is the only criterion for determining the implicit value of workplace risk. Therefore, to attract workers, firms with the most dangerous working conditions have to offer the highest risk premiums, as the financial compensation needed to undertake the perceived risk. Wages thus reflect the safety level for given jobs, and employers pay what is most likely to maximize profits. In this manner, both workers and employers have a direct interest in reducing workplace health and safety risks (Boivin, 1993).

A government regulation is a public investment. When HRDC performs a cost-benefit analysis for a safety and health regulation, it evaluates the project in much the same way as it does a commercial investment. One important difference is in the point of view taken. For federal government analyses, the point of view is the entire Canadian economy, considering the sum of advantages and disadvantages for business, labor, consumers, and governments.

This paper discusses the cost-benefit methodology used in occupational safety and health regulatory development at Human Resources Development Canada (Labour Program). It describes the application of a trend scenario model and considers the inherent biases and limitations of this method.

THE TREND SCENARIO METHOD IN THE OCCUPATIONAL SAFETY AND HEALTH CONTEXT

What Is a Trend Scenario, and How Is It Distinguished?

A trend scenario predicts future economic conditions based on past and present empirical events. The method makes realistic assumptions about which variables will affect the future state of affairs, by holding all other criteria constant and by incorporating strategic information about the selected variables into a prediction model.

The trend scenario model used by HRDC–Labour to evaluate safety and health projects produces a net present value (NPV) for the cash flows by:

- applying risk factors for the named contingencies;
- adjusting the projection using the social discount rate and various price indices;
- including shadow prices for nonmarket goods or services;
- compensating for indirect costs; and
- adjusting for regulation effectiveness and rate of compliance.

The scenario method is an exploratory process, which starts from current reality and then projects past trends to predict a sequence of events culminating in some possible future state of affairs. The trend scenario controls its projections by adopting the *ceteris paribus* rule, which assumes no variation in external conditions, that is, “all other things being equal” (Boivin, 1993).

In reality, however, external variables may not remain constant. There will often be other possible outcomes. The scenario is based uniquely on assumptions related to the chosen criteria. Therefore, the results of the projection of future conditions must be carefully qualified.

How Are Benefits Estimated in the Trend Scenario?

There are six steps to quantifying benefits in the trend scenario.

The first step is to identify in conceptual terms how Canadians and their economy would be better off. In most cases, this involves less occupational injury/sickness/death, reduced medical costs, lower insurance premiums, and increased economic productivity.

The second step is to identify those who would receive the benefits, meaning employers and employees in certain industries and the Canadian consumers.

The third step is to select an appropriate unit to measure each benefit. The best unit, if benefits can be so quantified, is dollars. In most cost-benefit analyses, economists apply market prices to the damages avoided, or they make "shadow price" estimates (defined below) for nonmarket items. Other quantification techniques include listing or estimating the extent of the potential social benefits, such as greater labor market participation for those who might otherwise not have access, or increased levels of health for given numbers of people. Ultimately, where no other hard measurement or estimation is possible, there is a type of ethical "yardstick." For instance, some people believe that maintaining human life and health justifies any expense, and so for them there is no question of costs ever exceeding benefits.

Nonmarket Benefits and Shadow Prices. Often, in regulatory impact analysis, it is necessary to "price" impacts or conditions that have no straightforward dollar value. Examples of nonmarket benefits include the value of improving working conditions for disabled or otherwise disadvantaged workers, of protecting the environment, or the value of human life and health itself. The dollar values estimated for items that have no market (shadow prices) enter the calculation of the benefits as imputed values.

Shadow-pricing occupational mortality is a unique challenge for cost-benefit statisticians, as presuming to place a dollar value on human life is a highly controversial activity. The arguments pro and con range from the emotional ("It is sacriligious to even attempt such a thing") to the commercial ("An individual's worth is equal only to his or her life insurance indemnity"). However, as adapted to a cost-benefit exercise, the central questions become: "Calculating the value of *whose* life?" and "In what *context* is this value to be applied?"

The cost-benefit analyses treat occupational safety and the valuation of human life *statistically*. What is being discussed is the *potentially saved life of a hypothetical worker*, who without particular safety measures would die of workplace illness or injury, given the existing level of risk in a particular occupation. This "statistical death" is an artifact of many workers taking small risks of a fatality. The approach for estimating the average value of an avoided statistical death is the *ex ante* or before-the-fact method, as opposed to the *ex post* method, which looks at after-the-fact criteria, such as court settlements or insurance payouts. The *ex ante* variable of most interest in the occupational context is the wage compensation premium paid to workers to accept a one-in-one-thousand increase in the probability of a work-related fatality (Meng, 1989).

There are several ways to estimate the implicit value of an avoided death, but the *willingness-to-pay* approach is the one with the strongest theoretical basis. This method assesses the attitude of workers toward an actual risk — their willingness to "pay," by trading off other goods and services to get a reduction in the risk of death. In occupational applications, it means the actual amounts workers are willing to pay through decreased aggregate wage premium differentials for a 1/1,000 reduction in the risk of death (Meng & Smith, 1990). Summing these amounts across the entire group will give an estimate for the value of a (saved) statistical life. Fisher, Chestnut, and Violette (1989) describe this amount not as the value of any particular individual's life, but what a specific group is willing to give up for lowering each group member's risk by a small amount. Other approaches to estimating the value of human life in similar contexts, such as those based on human capital, insurance premiums, or court judgments, are often biased and underestimate the value of an avoided death (Boivin, 1993).

In the willingness-to-pay approach, estimates may be made in either of two ways:

- Expressed preference (what people say they want — *ex ante*): by the choice of individuals to "pay" for a (standard 1/1,000) reduction in the probability of death through the introduction of regulations or safety measures (smoke detectors, inflatable airbags, etc.), or
- Revealed preference (what people usually do — *ex post*): by workers bargaining for an increase in their actual wages, equivalent to some kind of direct or indirect danger pay, when no additional safety measures are taken (Parisé, 1993).

In other words, the value to the economy of preventing death on the job can be expressed as how much less in wages employees will accept if working conditions are safer, or how much more in wages they will demand to do jobs where it is known there is an increased risk of death. After a thorough review of the relevant research, Fisher, Chestnut, and Violette (1989) recommended using a guideline value range of between $1.6 and $8.5 million (1986 constant U.S. dollars) for the value-per-statistical-life estimate, or what might be called the *implicit value of an avoided death (IVAD).*

When the saving of human life is at issue, there are many who would argue that no further weighing of costs and benefits is called for, as the outcome is one of the highest ethical and social priorities, thus transcending economics. Analyses using the IVAD do not take issue with that position. They concern only the impact on the Canadian economy of government safety regulations avoiding the loss of *statistical* (i.e., hypothetical) lives in a particular occupation.

The fourth step in estimating benefits is to determine how the numbers will change after regulation. The procedure is to calculate the risk probabilities, based on the types and extent of injuries and illnesses that have been occurring in recent years. For example, if a health and safety regulation is aimed at reducing sound levels at work, noise-induced hearing loss incidence rates per n workers would have to be gathered to estimate the risk for this condition. Once these risk statistics are compiled, estimates are made of the reduction in injury and illness cases resulting from the proposed regulation.

Step 5 is placing a value on each risk factor being measured. For instance, some unit values will include the average cost of a day in hospital, medical treatment and care, rehabilitation costs, or average wage rates for compensation claims, to name a few.

Indirect costs. Occupational illnesses and accidents also involve significant economic losses known as *indirect costs*. (Other names for indirect costs include uninsured costs, individualized costs, unrecognized costs, hidden costs, uncontrollable costs, and variable costs.) If some or all indirect costs are no longer incurred because a regulation has been introduced, then these avoided indirect costs are also benefits.

Indirect costs cover an extremely wide range. Though their effect is subtle, and often intangible, the effects may be real and extensive. Some examples of possible indirect costs associated with workplace illness and injury include the supervisor's intervention time (or the opportunity cost), transportation to a hospital, the extra premium payable to Workers' Compensation Boards, challenges to medical evaluations, costs of litigation, the costs to do work left unfinished, penalties for late deliveries, fringe benefits paid during a worker's absence, the potential negative effect on a firm's image, loss of production-related bonuses, the opportunity cost of co-workers' distraction time, deterioration of labor relations, and reduction in employee morale (Boivin, 1993).

Each accident can generate its own indirect costs, and these can vary greatly (Brody, Letourneau, & Poirier, 1990). In another work, Brody, Jalette, Letourneau, and Poirier (1990) proposed a multivariate method of estimating indirect costs, which was based on a modeling of the most significant variables. They proposed an overall ratio of indirect to direct benefits of 1:1 for the industries under Canadian federal jurisdiction.

The sixth and final step is to calculate the actual benefits, multiplying the risk values by the unit values, which are generally the numbers of workers at risk in certain industries or occupations. That is, each damage category avoided by the regulation has a benefit, which is the full cost avoided per unit times the number of units.

The grand total benefit for the project is taken by aggregating the annual total benefits over the given number of years in the projection.

How Are Costs Estimated in the Trend Scenario?

It is first necessary to identify who incurs the costs. Generally, the costs associated with the introduction or modification of occupational health and safety regulations are borne by business, labor, consumers, and government. Businesses may need to buy safety equipment, reconstruct workplaces, arrange new operating procedures, or absorb training costs, to name a few costs. Part of the business cost picture is competitiveness. To what extent might the new regulation affect competition among certain industries or companies? Employees may require safety training, or invest their own time in safety preparations. Consumers may ultimately have to pay more for some goods and services. Governments incur costs related to their compliance efforts and their enforcement costs, as there will be a need to train and deploy safety officers.

A list of all the actions that may be required of the regulated population is drawn up and these actions are costed (in dollars) using market prices where available, or with estimates. These costs most often include equipment purchase, administrative and data-processing costs, engineering controls, retrofitting of workplaces, training and education, and enforcement costs.

What Is the Structure of HRDC–Labour's Cost-Benefit Statistical Model?

Once all applicable benefit and cost items are listed and estimated, analysts enter all the statistical data into a model, which is designed to calculate the net difference of total benefits and total costs over a given number of years. A projection length of 20 years is standard; however, any number of years is possible for the trend scenario, as long as it is appropriate and realistic. For instance, if it is known that the industrial operation in question is not likely to exist after 10 years, then a 10-year projection would probably be used.

Benefit Parameters

The following entries are standard on the benefits side of the statistical model.

The number of employees is estimated using current levels and projected employment growth rates for the relevant industries or occupations.

Hourly pay rates are input as the current wage or salary rates (averaged if necessary) for the relevant industries. The scenario model allows adjustment to wage rates by a given percentage in each year of the projection, or values for specific years can be entered, such as when a long-term employment contract is in force.

The average cost of one day in hospital and the current costs of certain medical procedures, rehabilitation, and care are examples of hospitalization costs or medical payments. They exist as parameters for the model's reference, and are applied for each listed type of illness or injury where such expenses are involved.

The shadow price of avoided mortality (or the IVAD, above) is a fixed entry, representing the estimated average impact on the Canadian economy for one occupational fatality.

Shadow pricing for lost quality of life, similar to the shadow price for fatality, is a scale of values representing different levels of physical disability, and an estimate of how much an occurrence of each could cost the Canadian economy. The Labour model adopts the QALY (quality adjusted life years) method.

The benefits column also shows the *risk* for each injury or illness involved, which is the probability that one employee will suffer that contingency in a year. The unit cost of each identified contingency is then multiplied by the risk factor, giving the yearly benefit associated with a named morbidity.

Cost Entries

The following categories are listed in the model for reference. Dollar value estimates are subsequently entered based on their relevance to a particular application.

Direct costs
- *Nonrecurrent:*
  - *Research and development*
  - *Investment:* Training, equipment, system development, miscellaneous
  - *Working capital* (Inventory)
  - *Residual or final value:* Scrap value, resale, reutilization, in service
- *Recurrent:*
  - *Human resources:* Salary, social advantage, turnover, training
  - *Operational cost:* Equipment rental, equipment maintenance, space rental, space maintenance, systems, miscellaneous

Indirect costs: Accounting, litigation, security, administration

Statistical Factors and Indicators

Parameters and projection tools stored in the cost-benefit model for the 20-year predictions include:

- Projections of the consumer price index (CPI)
- Projections of the industrial and farm price indices
- Social discount rate
  According to the Treasury Board's benefit-cost guidelines (Treasury Board Secretariat of Canada, Planning Branch,

1976), the benefits and costs of government expenditures may be realized at different times, and this fact will affect the viability of projects. *Benefits realized in future years are less valuable because they are not available for immediate consumption or reinvestment*. Therefore, the benefits calculated annually are reduced (or discounted) to compensate for not having the total (20-year) benefit immediately in hand. To more effectively evaluate this public investment and to account for the time differences, the application of a discount rate converts benefits and costs into present values. Treasury Board guidelines call for the application of a standard social discount rate of 10%, and then a comparison for sensitivity at 5% and 15%. The 10% rate is factored into the costs and benefits in the model, to calculate a net present value.

- Regulation effectiveness
  Ideally, if all possible occupational injuries, sickness, and mortality could be eliminated from a given industry, owing exclusively to the introduction of a regulation, then that regulation would be 100% effective. In practical terms, employers and employees usually abide by voluntary safety guidelines, which anticipate much of a proposed regulation's content. *The value added by a regulation will derive from the incentive for employers to change operating procedures in light of compliance requirements*. In practical terms, a new regulation is likely to make the work only *x*% safer in total, as it is effective only above whatever safety measures are already in place.
- Compliance rate
  This factor is an estimate of the extent to which the regulation might be obeyed by workers and employers. Not all concerned parties may comply fully with every detailed regulatory requirement in day-to-day operations, although that is the intended, ideal state of affairs.

What Are the Outputs of the Trend Scenario Model?

The dollar values from all the costs and from all the benefits over the 20 years are aggregated in constant dollars and reconverted into current dollars for reporting the summary.

Net present value. Subtracting the present value of the accumulated 20-year discounted costs from the present value of the accumulated

20-year discounted benefits gives the net present value (NPV). The NPV of a given program over 20 years, with social discount rate taken at 10%, will be in the format of "benefits exceeding costs by $\$x$." At least, this is the desired state of affairs. If the NPV is negative, meaning costs are higher than benefits, the government will not recommend the regulatory project.

Sensitivity estimates. Sensitivity means that the cost-benefit result, the NPV, may vary greatly, based on the value of certain of its components. The NPV may be sensitive to certain input variables, such as the social discount rate, the number of workers, or the effectiveness of the regulations. In such cases, a *risk analysis* (probability distribution of NPVs) may be called for. Sometimes, if the NPV is highly sensitive to certain variables, a distribution of NPVs is the means to reduce the uncertainty involved. A risk analysis (stochastic simulation) can give the probability that the NPV is positive. Analysis of the NPV estimates derived during such a simulation can yield the range, the mean (or expected value), and standard deviation for the NPV. For instance, if it is not certain whether the number of employees after 20 years will be as high as 500 or as low as 1, 500 NPVs are calculated, using every possible value of number of employees, giving the probability that the real NPV will be at least the amount *A* or at most amount *B*. How much confidence one may have in the NPV of a cost-benefit analysis depends on its sensitivity to changes in the values of the individual cost or benefit parameters.

BIASES AND LIMITATIONS OF THE MODEL

Analyzing costs and benefits is a scientific way of attempting to predict the future. The nature of prediction is such that one cannot be certain whether the future will happen exactly as foreseen. To justify the conclusions of an analysis, all assumptions will be clearly stated and the methods will be fully described.

What Are the Potential Intrinsic Biases of This (or Almost Any) Prediction Model?

Problem Definition

A cost-benefit analysis is only as good as its definition or the number of consequences it considers. Any adequate analysis must start with a succinct definition of the problem. An explicit definition reduces the possibility of omitting important consequences and increases the chance of including new options, consequences, and information. Cost-benefit analysis, as a statistical technique, offers no guidance in determining whether the model is complete or well defined.

Depending on how the problem is formulated, certain consequences can be omitted from a cost-benefit study, producing highly significant changes in NPVs for the project. For instance, in a particular study of noise-induced hearing loss resulting from long-term, continuous occupational exposure to excessive noise levels, an initial scenario listed as benefits only the avoided medical costs. In that scenario, the problem definition limited the NPV to about $2,000. The benefits in a subsequent hearing loss study included quality-adjusted life years (QALY), which is an imputed dollar value representing the average potential loss of enjoyment of life for the number of workers who would otherwise lose some of their hearing. All other things being equal, the problem definition including the QALY gave an NPV of over $1 million, from a considerably higher total of benefits than the analysis that excluded QALY.

One way around problem definition difficulties may be to introduce multiple scenarios. In the occupational safety and health context, it is often advantageous to do cost-benefit analyses on more than one projected set of outcomes, and to allow reviewers to select the assumptions and results they believe are most applicable. For instance, if a certain technology is being developed within the next 10 years that would severely reduce the risk of a particular work injury or illness, but it is not known if or when this technology will appear, it may be advisable to write one cost-benefit study, using two scenarios. The first scenario would evaluate the costs and benefits of having the new technology; in the other scenario, the only assumption is the status quo. For example, assume that an occupational health regulation aimed at preventing a certain type of cancer is being evaluated, and there is current medical research ongoing for this same type of cancer. The research would result in one of two situations: a cancer treatment publicly available in 10 years, or no treatment available at all. If an effective treatment became available halfway through the project, the resulting decrease in morbidity would substantially reduce the regulation's benefits; therefore, two studies could be done, one for each cancer research scenario. However, the NPV of the selected scenario would have to be positive for the project to go ahead.

Factual Knowledge

The model operates on what is or is not known about the industry in question, and how well the analysts have arranged their parameters or assumptions. Every scenario analysis can organize all the facts effectively and explicitly, but uncertainty often affects the facts. It is often difficult to combine data with a subjective judgment, or to deal with uncertainties to which no relative frequency is attached.

Statistical techniques can represent and deal with probabilities, but the value of the analysis usually relies on the analyst's judgment. The greatest improvements in analytical technique and factual knowledge for the occupational safety and health program will likely come about in future research on indirect costs and the social discount factor, and in the rates of regulation compliance and effectiveness.

Unstable Values

Popular values and preferences often vary over time. By inferring preferences from labor market historical data, cost-benefit analysis may sometimes be falsely assuming stable values. This is particularly true of expectations for wage and employment conditions, when a 20-year scenario is projected. For example, economic events to occur in the next few years may reveal that baby-boomer career values of job continuity and prosperity-level wages may not be the occupational objectives of their offspring, the so-called Generation X.

Shadow Prices

Shadow prices are a highly controversial issue in occupational safety and health, and there is no consensus on the best methods to use for valuating human life or well-being.

The IVAD, or implicit value of an avoided death, has been known to vary in different research applications, with the applied context — the criteria differ greatly, depending on whether the topic is road safety, medicine, or health in the workplace; the particular methodology used — within a single methodology, the value of willingness to pay can vary by up to $7M; or the latency period of an illness (e.g., a relatively long time with cancer, a shorter time for pneumonia). Perhaps the best way to understand the IVAD is as a substitute points rating system, *not* for estimating the value of human life as such, but for evaluating the relative benefits from the introduction of safety regulations in the workplace.

CONCLUSION

The trend scenario method of analyzing costs and benefits in occupational safety and health regulations enables a comprehensive cost-benefit evaluation model involving past trends and parameter projections. It is seen as improving reliability and control over the predicted results.

A trend scenario predicts future economic conditions, based on past and present empirical events, by making realistic assumptions about which variables will affect the future state of affairs, holding all other criteria constant (the *ceteris paribus* rule), and by incorporating strategic information about the selected variables into a prediction model.

The trend scenario model used by HRDC–Labour to evaluate safety and health projects produces a net present value for the cash flows by applying risk factors for the named contingencies; adjusting the projection using the social discount rate and various price indices; including shadow prices for nonmarket conditions; compensating for indirect costs; and adjusting for regulation effectiveness and rate of compliance.

The intrinsic biases and limitations of applying trend scenario models in cost-benefit analyses include problem definition, how limited factual knowledge is set out in parameters or working assumptions, unstable values or preferences, and shadow pricing, especially the controversy about the statistical value of human life and health in the occupational context.

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