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Guide to cost benefit analysis of community-based interventions

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Abstract

This paper offers a general guide on how to conduct a proper economic analysis for community-based intervention projects. Identification and quantification of costs and benefits are the focus of the cost benefit analysis. We categorize costs and benefits from human and physical perspectives and pay special attention to the measures of saving human lives accompanied by the proposed calculation methods. We recommend net present value and benefit-cost ratio as the criteria to assess projects and highlight some challenges remaining in the analysis.

Key words

Cost benefit analysis, Cost effective analysis, Community based interventions, Economic impact studies, Health economics

1 Introduction

During the past three decades, humans have witnessed a higher frequency and larger costs of both natural and man-made disasters around the world than any other time in history [1]. Both developed and developing countries unavoidably are the victims of the more frequent and destructive disasters. The losses of human lives, properties and infrastructures in the previous large scale disasters all address the importance of social networks, community capacity, emergency preparedness and mitigation plans which influence the transformation of an emergency into a disaster, particularly in demands for services and community response capacity. This paper provides a general guide for assessing community-based intervention programs that intend to improve emergency preparedness, resilience and response in target communities. Particularly, it focuses on selecting the proper economic analysis, identifications of the costs and benefits and measures to evaluate interventions. Economic evaluations are used to assist in setting priorities, making resource allocation decisions and designing services when there are competing health interventions and limited resources.

2 CBA vs CEA

Cost benefit analysis (CBA) and cost effective analysis (CEA) are the two most common economic evaluation approaches. They have grown from different historical traditions and have been adopted for different reasons. CBA is developed primarily to assist in making decisions about the provision of public goods while CEA is more often used in the private sector. Under some circumstances, they appear to give nearly equivalent results [2]. However, in principle, CBA is more general than CEA [3]. CBA requires placing monetary values on the outcomes of any program or intervention. In the context of health and medical care, making that valuation can be equivalent to placing a dollar value on a human life (or, more precisely, on changes in the probability distribution of the length or quality of human life), which has not been generally accepted by many in the medicine and public health academics. In this project, CBA is a more appropriate way of conducting economic analysis since the interventions fall in the category of providing public goods.

3 Cost benefit analysis

In general, CBA consists of two types of analysis: financial analysis and economic analysis. Financial analysis takes a narrow perspective of the costs and benefits which are directly measurable, focuses on calculating the net cash flows during the lifespan of a project, and ignores the price distortions in the markets. Economic analysis has a much broader perspective and adopts a more societal view. Indirect and some intangible costs and benefits are contained in the economic evaluation. Market distortions are also taken into consideration, and adjustments will be made to offset market imperfections if necessary. One important procedure in CBA is to identify alternatives. In order to archive the socio-economic goal of a project, several interventions could be available, but each would possibly result in different outcomes. By comparing these outcomes, researchers are able to rank them and find the most cost-beneficial intervention. A common alternative is taking no action which serves as the benchmark scenario. The comparisons between other interventions and the benchmark scenario will provide incremental changes of each pair, and help to determine the best intervention. Costs, benefits and assessing criteria are three fundamental elements of CBA. In the following subsections, we shall discuss identifications of costs and benefits as well as the difficulties and challenges.

3.1 Identification of costs

Costs are identified as those which change values to the economy, and take place during the lifespan of a project but not the ones that occur prior to a project. In economic analysis, some activities, such as sunk cost, interest payments, taxes and subsidies, are not included. Costs are often categorized upon the measurability into direct and indirect cost. The direct cost has four major categories: capital/construction cost, implementation/management cost, maintenance cost and labour cost. Indirect cost is referred to the negative externalities, side effects, spillover effects, secondary effects and intangible cost. Intangible cost is difficult to measure in practice and sometimes requires some non-market approaches to estimate. It consists of any cost that is not directly measurable with the current market information, but could have potential influence on the project, *e.g.*, business disruption, caution, fear, suspicion, historical and cultural values, and environmental impacts. In a community-based intervention project, the direct cost of interventions should contain facility rentals, participant expenses, printing, meeting logistics, and supplies for intervention packages. Moreover, management cost, labour cost and other directly related costs of participating organizations in the interventions should also be included in calculation of the total cost of a project. However, more information about the interventions is required to characterize and measure the indirect cost.

3.2 Opportunity costs

Opportunity cost is defined as the foregone value of the resource/input used in other alternative ways. It is an important economic concept since it relates resource scarcity to choices of an economic agent. It has been widely applied in social project evaluations, such as to estimate the value that consumers place on forgone consumptions, the value of the material and productive service in the absence of producers, and the value society sets on a given good or service diverted to another use. In a competitive distortion-free market, the social opportunity cost of goods and services is equal to the competitive market price. However, market imperfections cause opportunity costs to deviate from the competitive market price, thus price adjustments are needed to correct the market distortions (taxes, subsidies, policies, *etc*.). Shadow price and shadow wage rates of labour are applied to overcome the market distortions. Shadow price is the price that analysts attribute to a good or service that is considered to be more appropriate than the existing price. It represents the true willingness to pay of the society after applying non-market approaches to properly correct the distortions. Wage rate in a competitive market displays the true opportunity cost of labour, but government or union interventions (minimum wage) make wage rate an inappropriate measure of opportunity cost of labour. A shadow wage rate that is equal to the marginal product of labour can be estimated to reflect the opportunity cost of labour. Empirically, to measure opportunity cost is difficult, and it remains a significant challenge to a community-based intervention project. We need to identify and categorize any possible opportunity costs, and either to quantitatively estimate them by non-market approaches (reservation wage) or to assign the corresponding market prices to goods and services.

3.3 Expected costs of disasters

Uncertainty is always a problem in any empirical analysis, and particularly when it is used to measure the "human" cost. Dore (2002) suggests that the best way to learn from the past is to forecast the conditional probability of the "return period" of a disaster and estimate the expected cost by understanding the frequency and weather pattern of disasters over time from statistical data [4]. A community-based intervention is designed to have a certain lifespan that includes an intervention period. Within the lifespan of a project, we are uncertain about what disasters would occur, and how often and how large they would be. However, it is necessary that we incorporate the possible disasters in targeted communities to estimate the expected cost. One suggestion is to obtain the historical data on frequency of both chemical, biological, radiological and nuclear defense (CBRNE) and natural disasters, and the recorded damages and casualties in each community. They will help us to identify the possible disasters and generate probability distributions of these events in each community. By converting all costs and damages into the present monetary value, we could have estimates of expected cost of each event and the overall expected cost of all possible events, which could be used in benefit analysis. The data could be collected from some government agencies, and empirical estimations and forecasts could follow Dore (2002). Although some of these costs can be better estimated with good survey data, it would be possible (use preferable instead?) that we apply the estimates from some existing international databases, such as Swiss Re, Munich Re, the Economic Commission for Latin America and the Caribbean (ECLAC) and the EM-DAT database from the Centre for the Epidemiology of Disasters (CRED) in Brussels. However, it may be impossible to touch upon all aspects of human costs as discussed in literature.

3.4 Identification of benefits

Contrary to the classifications of costs, benefits take the exact reverse meanings and sign. Direct and indirect benefits are the two fundamental types which are similar to the categorization of costs. From a broader point of view, the benefits can be identified as individual and physical benefits. Measuring benefits in CBA attracts most attention from researchers and is the core to assess a social project. In most disaster research projects, there are mainly two types of benefits estimated – the savings of damages and savings of human lives.

3.5 Saving of damages

Otero & Marti (1995) define the savings of damages as the difference between the damages occurred with and without additional disaster management, and further categorize the damages into three types, direct damage, indirect damage and secondary effects [5]. "Direct damage refers to all damages to fixed assets, capital, and inventories of finished and semi-finished goods, raw materials, and spare parts. It includes total or partial destruction of physical infrastructure, buildings, machinery and equipment, transport and storage facilities, and furniture as well as damage to farmland and soils, irrigation and drainage works, dams, etc. Indirect damage refers to damages to the flow of goods that will not be produced and of services that will not be provided after the disaster strikes". The period of time covered begins immediately after the disaster and may last several months or years, depending on the type and characteristics of the disaster. Indirect damages are measured in monetary terms but not in physical numbers. The sum of direct and indirect damages represents the total material and monetary damage inflicted by a disaster. Secondary effects refer to the impacts of a disaster on the overall economic performance of a country as measured by the most significant macroeconomic variables. In addition to the categorizations by Otero & Marti (1995) [5], Ganderton (1998) [6] introduces the intangible impact which includes a greater sense of security, increased awareness of hazards and other psychological preparations in communities. In reality, people value these "feelings" but they are difficult to evaluate. Given the nature of the interventions, the expected savings of disasters could be calculated from the expected cost, which could be based upon expert's advice in the communities and practical evidence of the effectiveness.

3.6 Saving of human lives

Horowitz & Carson (1990) point out that it is unavoidable for analysts to place dollar values on human lives for projects which intend to reduce risks of mortality [7]. Measuring the savings of human lives requires estimations of the value of statistical life (*VSL*), probabilities of survival, and possibly quality of life. Economists have developed some theoretical models to define *VSL*, and provide estimates on *VSL* empirically.

3.6.1 Value of statistical life

The methods to estimate the value of statistical life have been evolved rapidly over the last four decades, and are summarized by Mishan (1971) into four categories: gross output approach, net output approach, social welfare approach and insurance principle approach [8]. The insurance principle approach has received the most attention of researchers, but since the late 1980s, the optimal deterrence amount approach has been developed to take over the insurance principle approach and become the major estimation method in *VSL* studies. The two output approaches are under criticism. Mishan (1971) argues that calculation of the loss of potential future earnings of a person by gross output approach contributes directly to GDP (GNP), but in principle, maximizing GDP (GNP) is not equivalent to optimization of economic policies [8]. The net output approach couldn't explain the case when loss is negative. Obviously, retired people and those who are taking social welfare benefits would have negative values of life, and the conclusion implies that deaths of these people would increase the net benefits of the society. He comments that "it restricts itself to the interest only of the surviving members of the society: it ignores society ex ante and concentrates wholly on society ex post". Fromm (1965) assumes a linear relationship between the probability of a person being killed (*p*) and the sum that the person would like to pay to cover the risk (or insurance premium *y*), and defines value of life as *y*/*p* [9]. This simple specification of calculating the value of life has been the fundamental to later studies. Viscusi (2004) explains the optimal deterrence amount approach by setting up a theoretical model and proposes an empirical regression. He assumes that a non-risk-loving worker chooses a job with fatality risk *p* by facing a set of possible market offers *w*(*p*). The utility depends on the fatality risk and has two values associated with the good health and death states, respectively. Thus the expected utility of the worker is a function of the fatality risk *p*. The tradeoff between *w* and *p*, *dw*/*dp*, represents the willingness to pay (*WTP*), and *WTP* is increasing with respect to both *w*(*p*) and *p*. The empirical regression suggested by Viscusi (2004) is [10]:

$$\ln w_i = \alpha + X_i'\beta + \gamma_1 p_i + \gamma_2 q_i + \gamma_3 WC_i + \varepsilon_i \quad (1)$$

where w_i is the wage of worker i, X_i is a vector of the worker's personal and job characteristics, p_i is the worker's fatality risk, q_i is the nonfatal injury and illness risk, and WC_i is a measure of the worker's compensation benefits. Not all labor market studies of *VSL* include q_i and WC_i terms.

The estimate of value of statistical life is:

$$VSL = \frac{WTP}{unit\ of\ probability\ of\ death} = \frac{\widehat{\gamma_1} * (sample\ average\ annual\ income)}{unit\ of\ probability\ of\ death} \quad (2)$$

where researchers usually use deaths per 10,000 as a measure of unit of probability of death. In practice, researchers have discussed some statistical issues, such as heterogeneous preferences of individuals, variations across ages, occupations, industries and health status, endogeneity of risk, self-selection bias, *etc*. Empirical estimated *VSL* of the Canadian labour market from previous studies are reported in Table 1. In this project, we could estimate the *VSL* by employing the information of the vulnerable population groups, or apply some empirical estimates in the existing literature if information collected was not enough. The risk of doing so is that these results may only be applicable to certain samples of the Canadian population, and cannot capture the time variability of the *VSL* implicitly. Therefore, the accuracy of these estimates remains questionable. In the case of conducting surveys, the much more complicated questionnaires and more demanding for human resources would be concerns, and could possibly cause an increase in the budget. Even if the surveys became available, the analysis would require a lot of work and the results could be very sensitive to inclusions of variables and techniques applied.

Table 1. Value of statistical life of Canadian labour market

Authors	Year of publication	*VSL*	Standard error of *VSL*
Meng	1989	4,041,961	2,336,394
Meng and Smith	1990	1,216,395	2,252,583
Cousineau et al.	1992	4,804,628	464,664
Martinello and Meng	1992	3,144,141	949,892
Lanoie et al.	1995	24,198,149	7,657,642
Meng and Smith	1999	2,353,931	609,827
Gunderson and Hyatt	2001	24,361,374	3,460,422
Average		9,160,083	2,533,061

Note. *VSL*s are measured in constant 2,000 US dollars. The results are cited from Bellavance *et al*. (2009) [11].

3.6.2 Probability of survival

Another key element of estimating the savings of human lives is to measure the probability of survival of each individual participant. In most empirical literature, the probability of fatality is obtained from statistical profiles across various occupations, ages, genders and other demographic characteristics, but none of them have involved any time setting. One goal of the interventions in this project is to enhance the preparedness and response of these communities, thus it is the incremental probability of survival of each individual participant that is more relevant to the CBA. A Probit/Logit model could serve as an option to approximate probability of survival, and the estimation process can be summarized preliminarily into three stages. The first stage is to conduct a pre-intervention survey on target vulnerable population groups on levels of preparedness and response for a variety of possible disasters along with the information on their financial status (possibly income expenditures and taxes), health status, *etc*. The dependent variable could be discrete which indicates the individual's own expectation on his/her overall preparedness and response level, *e.g.*, a scale from 1 to 5, or we could generate an index of overall preparedness and response levels based on the information we collect from respondents.

In the second stage, we could conduct a series of post-intervention surveys on the same target vulnerable population groups on levels of preparedness and response. It might be necessary to design the questionnaires differently from the pre-intervention one in terms of descriptions or/and orders. We could identify the improvements of the respondents' preparedness and response levels after the interventions.

The third stage will involve data integration, data cleanup, data analysis and regression analysis, and particularly will focus on:

Choosing Probit/Logit models. An ordered Probit/Logit model will be employed if an order of discrete choices is specified, and a multinomial Probit/Logit model will be used if no such an order is in place.

Examining the consistency and efficiency of the models estimated with some statistical standards and criteria. A natural experiment is to perform regressions with the pre- and post-intervention samples and whole longitudinal sample, respectively, and to compare the differences in the estimates. We may then either have to choose to regress with the longitudinal data if no statistically significant differences of estimates are observed, or with two sub samples given the statistically significant differences in the estimates.

Calculating the predicted probabilities of each individual's preparedness and response level pre- and post-interventions, and further deriving the increased probability of survival. The product of this increased probability and *VSL* of each individual gives the expected benefit on a personal level, and we could find the overall benefit by integrating all individuals' benefits for each community.

There are a few challenges of this approach. First, the application of *VSL* could quite possibly lead to a huge amount of benefits. Second, it might be possible that we find a decrease of probability of survival. Third, it is a strong assumption that the interventions would benefit an individual over his/her entire life, thus a certain foreseen period might be a better choice. Finally, the estimated benefits could be sensitive to the discount rate.

4 Cost benefit analysis criteria

Researchers have developed some CBA criteria, among which the net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR) and wealth-maximizing rate (WMR) criterion are most popular. In this project, we recommend NPV and BCR criteria, since they are more widely employed in CBA, more convenient in calculation, share similarities, and have easier interpretations.

Net present value and benefit cost ratio criteria

A common feature of the two CBA criteria is the discount rate which serves as a fundamental in calculation. A discount rate is synonymous to an interest rate and used to convert all benefits and costs to present values. It refers to the time value of money from a society's point of view and captures the time preference for current consumption over future consumption. It is the sum of riskless cost of capital and risk premium, and is considered as the opportunity cost of the rate of return that could be gained if alternative investments are implemented. Traditionally, long-term interest rates of government bonds have been used as a measure of cost of capital and adjusted by a risk premium which depends on the riskiness of a project. Another approach for estimating the discount rate in previous studies is using a weighted average of the economic rate of return on private investment and the rate of time preference for consumption. The social discount rate (SDR) recommended by the Treasury Board of Canada Secretariat (2007) is at 8% [12]. Boardman *et al*. (2010) argue that this SDR is not measured properly and is too high, while alternatively, they suggest an SDR of 3.5% by estimating the consumption rate of interest in a growth model [13]. The calculation of either NPV or BCR is defined as a discounting process which employs the discount rate to convert a stream of costs and benefits take place over a project's lifespan into present value. Discounting allows a systematic comparison of costs and benefits of a project or policy interventions occur in different time. The intuition behind discounting is that money today is not the same as money tomorrow, and individuals prefer money today than tomorrow and prefer to make payments later and receive benefits today.

The formulae of the two criteria are:

$$NPV = PV\ of\ benefits - PV\ of\ costs = \sum_{t=0}^{N} \frac{B_t - C_t}{(1+r)^t} \tag{3}$$

and

$$BCR = \sum_{t=0}^{N} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} \text{ or } Net\ BCR = \left[\sum_{t=0}^{N} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}\right] - 1 \tag{4}$$

The feasibility requirement for NPV criterion is that the NPV is positive, in other words, the present value of total benefits exceed that of the total costs. Similarly, a project is feasible as long as the BCR is greater than unity or net BCR is positive. An important feature of the two criteria is that they are subject to the scale of a project, *e.g.*, a relative bigger-sized project with a high investment cost may be rated lower than a smaller-sized project under both criteria. Each of the criteria will provide a unique result that can be compared with the corresponding decision rules. In this project, we could compare and rank the NPVs and BCRs of all alternative interventions if available, and the results may not indicate consistent rankings but can still provide useful information. If no alternatives are proposed, the results highlighted by the two criteria will draw the same conclusions on feasibility.

5 Other CBA applications

Robertson *et al*. (2001) employs Heckman self-selection technique to detect self-selection bias and estimate marginal benefit-cost ratio of two different interventions in a project that aims to reduce juvenile crimes [14]. The model is specified as:

$$\text{Completion} = \text{f}(\text{D}, \text{H}, \text{P}, \text{B}, \text{T}) \tag{5}$$

$$\text{Expenditures} = \text{f}(\text{D}, \text{H}, \text{P}, \text{B}, \text{T}, \lambda) \tag{6}$$

where *D* is a vector of demographic characteristics, *H* is a vector of home environment, *P* is a vector of personalities, *B* is a vector of behavioral characteristics, *T* is a vector of intervention types, and λ is the Heckman self-selection bias. Their estimation results of equation (6) provide a direct measure of expenditure savings of each intervention which is defined as the benefit to the justice system. The negative coefficient of one intervention indicates savings of expenditure for an additional participant and its value shows the size of marginal benefit, however, the positive coefficient of the other intervention suggests higher expenditure for an additional participant, which is not cost beneficial. They further calculate the BCR by taking the ratio of marginal benefit estimated and the marginal cost obtained from data.

We could consider this method as an alternative, and estimate a set of similar regressions to examine the marginal BCR, and later compare the results with what we would obtain by using the discounting method after data become available. Preparedness involves a large amount of preparations by individuals within the community through formal training and education or/and physical equipments, as well as government or non-government organizations (NGOs) led programs and plans that are designed to provide capacities and guide people to cope with disaster situations. Distinct from most literature which focuses on planning, training and managing aspects without economic and financial quantifications, Simpson (2004) introduces preparedness indices to compute the level of preparedness and rank among communities [15]. There are 10 categories of preparedness indicators: *A*. Fire Protection; *B*. Emergency Medical Services; *C*. Public Safety/Police; *D*. Planning and Zoning; *E*. Emergency Management Office (EMO); *F*. Other Emergency Functions; *G*. Additional Community Measures; *H*. Hazard Exposure; *I*. Evacuation and Warnings; *J*. Community Resiliency (Recovery Potential).

The formula to generate the index is:

$$PM = 3(A + B + C) + 2(D) + 3(E) + 3(F) + G + (-)H + 3(I) + J \tag{7}$$

This method may help to quantitatively identify the strengths, weaknesses, opportunities and threats (SWOT) of each targeted community. Due to geological, socio-economic or some other fundamental differences among the communities, pre- and post-intervention comparisons could reveal the improvement of preparedness level in each community.

6 Conclusions

This paper addresses some fundamental issues related to the cost benefit analysis, identifications of costs and benefits along with some possible measures. Particularly, we propose a way to compute the benefit of saving people's lives by estimating the value of statistical life, probabilities of survival and quality of life, respectively.

The tangible costs are much easier to calculate, but the intangible ones are very difficult to evaluate and sometimes impossible. Thus, most literature suggests that we could either leave the unmeasurable intangibles or adopt non-market approaches to reveal their values, but we should further extend the categorizations of costs and benefits we have learned so far in future research.

The recovery phase is an area where more research is needed since its nature determines the difficulty to measure and indentify costs and benefits. Recovery starts right after the hazard events, and it will involve physical reconstructions and psychological recoveries in the communities. The physical reconstructions could be measured by the government funds available, food and equipment provisions, medical supplies, infrastructure rebuilt and donations, *etc.*, but the psychological recoveries may take a longer time and vary by individuals, hence become difficult to measure in monetary terms. The recovery aspects of the interventions need to be identified before any possible measures of corresponding costs and benefits can be generated.

The benefits could be both in the short-run and long-run, thus, we might also need to sort them out. For example, the resilience building and implemented disaster mitigation plans (*e.g.*, hospitals, transportation, food storage, evacuation plans, *etc*.) could provide regular service and education, and preserve as a symbol of safety and public confidence in normal times.

Although we are facing and will face challenges in designing a general guide on conducting a proper economic analysis for community-based intervention projects, we will keep an open mind to comments and suggestions for further improvements.

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