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THE UNCERTAINTY PROBLEM IN COST-BENEFIT ANALYSIS EXPANDED: A CURRENT REVIEW

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ABSTRACT

This article examines the current state of cost-benefit analysis and its limitations. The review was completed by looking at current literature of cost-benefit analysis with the most up to date developments. Currently, it faces known challenges in quantifying subjective human elements, incommensurable costs and benefits, difficulty in measuring and discounting future benefits and costs, and the potential lack of impartiality in regulatory settings. However, this article uniquely addresses a paradox in the analysis process itself related to the discovery of new information. Methods to mitigate risk and uncertainty, such as sensitivity analysis, Monte Carlo simulations, and scenario analysis, are analyzed. Additionally, quasi-option value is addressed as it relates the discovery of new information. Despite these approaches to mitigate uncertainty, uncertainty remains a fundamental challenge in achieving true optimality through cost-benefit analysis. However, it is found that despite the paradox identified in this article, it can still be a useful tool in evaluating decision alternatives.

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INTRODUCTION

Cost-benefit analysis is one of the more well-known decision-making algorithms. There are varying definitions of cost-benefit analysis, but the recognized definition is fairly uniform. Cost-benefit analysis has been defined as "a broad-based methodology developed by economists to assist in analyzing the advantages and disadvantages of a particular course of action" (Blum et al., 1980). Another definition states that "the basic rationale of cost-benefit analysis lies in the idea that things are worth doing if the benefits resulting from doing them outweigh their costs" (Sen, 2000). According to the Centers for Disease Control and Prevention (2021), "Cost-benefit analysis is a way to compare the costs and benefits of an intervention, where both are expressed in monetary units." The reoccurring idea in the definitions seems to suggest that if the benefits outweigh the costs, it might be a good idea to choose said alternative. Alternatively, if the costs outweigh the benefits, it would not be wise to proceed. The net result can be described as the difference between benefits and costs to where we can have a "net benefit" or a "net loss." As seen above, while the general idea is uniform, the precise definition varies (the CDC suggests that courses of action or "interventions" should be expressed in monetary units). Cost-benefit analysis finds its origins in Europe around the 1840s (Mishan and Quan, 2020). Cost-benefit analysis usage in environmental economics became mandatory by the US government in certain circumstances in the 1930s (Mishan and Quan, 2020). According to Mishan and Quan (2020), the US Flood Control Act of 1936 started the modern precedent of comparing costs to benefits. In particular, if the benefits exceeded the costs, then a flood control project would be deemed desirable (Mishan and Quan, 2020). However, there were no standard guidelines for implementing such comparisons between costs and benefits (Mishan and Quan, 2020). The first standard framework for conducting a cost-benefit analysis came from Eckstein, Krutilla, and McKean (Mishan and Quan, 2020).

Cost-benefit analysis has a number of well-known applications, with public projects perhaps being chief among them. Water projects, transport projects, land usage, health programs, and education programs are all valid cost-benefit analysis applications (Prest and Turvey, 1965). Cost-benefit analysis is also used in private, commercial applications to evaluate projects for their economic feasibility (Valacich et al., 2015). Cost-benefit analysis can be used in a multitude of business decisions unrelated to just a project (Stobierski, 2019). Given the ubiquity of the tool, it would not be unreasonable to say that the tool can be used for anything that needs objective economic scrutiny.

METHODOLOGY

The review was conducted via an analysis of academic literature on cost-benefit analysis uncertainty and risk management. In total, there were 50+ potential sources examined, with 20 becoming references which were downloaded from various academic libraries. Aggregate libraries were mainly looked at. In particular, EBSCO Academic Search Complete, Business Source Complete, JSTOR, and ResearchGate were examined. The research was mainly based upon various keyword combinations while using appropriate filters in searches. Example searches included starting with Cost-benefit analysis" to using "Cost-benefit analysis limitations", "Cost-benefit analysis efficacy", "Economic evaluation", and "Decision analysis." Searched articles were examined based on relevance. No bibliometric analysis was conducted as this research did not warrant it. In particular, impact factor was not examined due to the research on limitations of cost-benefit analysis being rather scarce. Research mainly took place in March of 2023.

Established Shortcomings

Despite its usefulness and presence in most enterprises, public projects, and personal settings, it is not without its shortcomings as we will see. One complaint is the lack of ability to quantify subjective human elements (Frank, 2000). Frank (2000) speaks at length about costs and benefits often being incommensurable. For instance, a developing country may invest heavily in fossil fuel power plants, discounting energy costs and allowing rapid industrialization. However, how would one tally and quantify the long-term environmental costs? Another example would be building a large-scale manufacturing facility in a previously enjoyed nature spot; many people may live and specifically have purchased a house where they enjoy a view of nature, now occupied by a manufacturing facility. Did the benefit of the manufacturing facility to society outweigh the cost of a lost view of nature to affected people? It can become extremely difficult to compare unlike costs and benefits, especially when such things are already difficult to quantify in the first place (such as the long-term environmental cost). How does one understand future environmental impacts considering the innumerable number of factors to consider, not to mention assigning monetary and non-monetary quantified values to these impacts? Rowell (2014) argues that there is difficulty in measuring and discounting future benefits and costs. Referencing the "temporal asymmetry," Rowell (2014) states that "chief of these implications is that temporal asymmetry undermines the possibility of meaningfully reciprocal relationships between the present and the future." Clearly, there is a need to account for this asymmetry in time. However, the means to do this are not entirely clear (Rowell, 2014). This difficulty is especially compounded by the fact that while we might be able to project into the short-term future, no one is a fortune teller and cannot account for the innumerable mathematical combinations events could take (particularly on a global scale with environmental regulation). Rowell (2014) argues that agencies can account for the future more than they currently do. In particular, Rowell argues the importance of choosing an endpoint for any given analysis. This is predefined for agencies that have statutes regarding the cutoff point of an analysis (Rowell, 2014). For instance, "Most EPA rules, for instance, use scopes less than fifty years—three rules proposed by EPA in 2014 used 2022, 2030, and 2050 as their end points—but I have already cited one instance where the Environmental Protection Agency performed an analysis with a 10,000-year scope." (Rowell, 2014). For those agencies that are not bound by statute, agencies "should cover a period long enough to encompass all the important benefits and costs likely to result from the rule. (Rowell, 2014,)." Specifically it is stated "This proposal is that agencies should include an end point to their time scope that extends at least to the "temporal breakeven point"—the time point at which the rule has become cost-benefit justified in terms of current dollars." (Rowell, 2014). Rowell (2014) identifies that cost-benefit analysis all consider being cost-benefit justified but no order has been established that identifies when those rules must be cost justified. This is the temporal break even point (Rowell, 2014).

The last established criticism I will present is that cost-benefit analysis has been reported as not truly being impartial within regulation settings (Driesen, 2005). In the vast majority of cases, it has been shown to be anti-environmental (Driesen, 2005). The United States Office of Management and Budget (OMB) is an agency that "oversees the implementation of the President's vision across the Executive Branch" (United States Government, 2022). Examining a study conducted by the General Accounting Office about the regulatory rules reviewed by the OMB under the George W. Bush administration, it was found that the OMB in practice was anything but neutral in terms of the regulation policy review (Driesen, 2005). According to Driesen (2005), the General Accounting Office reported that the OMB "had significantly affected 25 rules" reviewed under the George W. Bush administration. In a review of the regulation rules, it was found that in 24 out of 25 cases, the OMB suggested weaker safety, environmental, or health protection (Driesen, 2005). This study suggests how in practice, cost-benefit analysis is not neutral in the environmental regulation setting.

The Cost-Benefit Analysis Paradox

The first issue I present with cost-benefit analysis concerns the core tenet of the theory. As established, the theory inherently suggests one should make the most efficient and economically sound decision relative to net gains/losses for each alternative in a set of alternatives (economically is used to indicate resources used including money and non-tangibles like effort, time, hardship, etc). The more factors one considers, the greater the complexity of the analysis. At what point does one arbitrarily cut off the scope and consideration of variables in the analysis for the sake of achieving an optimal one? The sunk cost of performing the analysis becomes a significant consideration as performing it could potentially outpace any realized benefits. Additionally, knowing the optimal time to spend on a cost-benefit analysis for maximum benefit is rendered impossible, since we cannot possibly know the complete horizon of benefits related to costs. The problem becomes magnified as there cannot be any foreknowledge of when the sunk cost intersects with any realized benefits over various time periods. The only way to find out potential net gains or losses is to commit oneself to the analysis, incurring the sunk cost of doing so. Herein lies a problem and a paradox of cost-benefit analysis.

We shall call this paradox the "optimality problem." To be clear, the optimality problem is the issue of not knowing when to end a cost-benefit analysis relative to new information that could be gathered. It is intuitively known that generally speaking, the more information you have to make a decision, the better. However, not all information will be available to one entity in the immediate term, so they must wait to gather more information to make a better decision in a cost-benefit analysis. This results in a theoretically infinite time horizon that has no end since we cannot know future benefits relative to costs at any future discreet points in time. In theory, there could be a great payout to waiting 50 years to make a decision on whether to enact legislation to mandate carbon emission controls through electric vehicles. By that time, we will have gathered much more information and better quality information on the effects of such legislation. Quasi-option value is a concept that addresses this but does not resolve the problem, as I will identify later.

The optimality problem is a consideration for all cost-benefit analyses regardless of initial scale, complexity, or entity. That is to say, the optimality problem affects every cost-benefit analysis in principle. The costs and benefits will vary in size relative to the entity and analysis in question, but consideration of the net effect of an action is still subject to the optimality problem. The reason for this is that an entity could never know every discreet point of net cost or net benefit in the future from a decision, regardless of the size of the decision. This is because we cannot predict the future and know what unfolds as a result of our decisions. Whether to approve a project in an organization will be just as subject to the problem as whether to mandate a proportion of all new cars built needing to be electric. In the former example, whether to approve a new project might consider employee morale after the initiation and implementation of the project, which could predict general work performance. However, the company may wait to estimate such a morale change until a psychometric is developed to objectively measure it. Was the time waited worth it? It is a guess at best whether to wait and how long to wait for future information that could benefit the analysis of the decision in cost-benefit analysis. Take the instance of someone wanting to achieve the most wealth through buying and selling various asset classes. They perform a cost-benefit analysis of various methodologies, such as buying and selling real estate, value investing, short-term trading of stocks, futures, and options contracts. One can argue that each type of asset class has its own advantages and disadvantages under various circumstances. Further, it might also be argued that each particular asset class has its own methodologies for buying and selling to achieve a particular outcome. For instance, just within the equity's asset class, one could engage in value investing (Hayes, 2023). According to Hayes (2023), value investing is "an investment strategy that involves picking stocks that appear to be trading for less than their intrinsic or book value." To find out if a stock is trading below intrinsic or book value, one can examine metrics like price-to-book, price-to-earnings, and free cash flow (Hayes, 2023). One could also engage in growth investing. According to Segal (2023), "Growth investors typically invest in growth stocks—that is, young or small companies whose earnings are expected to increase at an above-average rate compared to their industry sector or the overall market. Growth investors may use certain methods or criteria as a framework for their analysis, but these methods must be applied with a company's particular situation in mind" (Segal, 2023). To make a prudent decision about which method to use, both sub-methodologies of buying and selling equities just within stocks alone will require time and further research to determine which can provide superior risk-adjusted returns (this would be a uniformly accepted statement by finance professionals). Multiply the work needed to research each method of buying and selling each product in each asset class (as each individual method is contained within the original scope of "wanting to achieve the most wealth through buying and selling various asset classes") by each financial product, and the sunk costs rapidly add up. These sunk costs in time, effort, money, and opportunity cost will need to be recouped for it to be worthwhile. Most importantly, the person doesn't know the optimal number of resources to use for the greatest net benefit.

The underlying issue with the previous example and cost-benefit analysis at large rests on uncertainty. Let's propose that the person in the previous example commits themselves to understand every known buying and selling strategy, weighing every pro and con until they find the most optimal strategy that meets their constraints. If this takes merely a few years for a considerable financial gain, then so be it. But what if this takes 20 years of trial and error, with much time and money lost? If the person quits their research due to great effort with no significant gains, is this person on the verge of the perfect strategy, promising great personal fortunes only to quit before they realize them? One cannot know when to end a cost-benefit analysis if one does not know what kind of future gain or loss could be realized from further consideration of variables with respect to both sunk costs and potential benefits. How does the person buying and selling assets know when the optimal time to end their research in finding the most mathematically optimal strategy when they do not know what could lay ahead at any given point in time in terms of total costs and total benefits? As previously established, while the entire point of a cost-benefit analysis is to pick the decision among a set of alternatives with the greatest net benefit, this can be hindered by, and sometimes completely derailed by the entire process in and of itself.

Ways to Manage Risk and Uncertainty

There are ways to mitigate risk and uncertainty. First, we must define both risk and uncertainty. According to Salci and Jenkins (2016), Risk exists when the potential event or outcome can be reasonably identified and estimated with a certain degree of confidence (e.g., annual rainfall, wind intensity, movements in relative prices). Uncertainty exists when the potential event or outcome cannot be reasonably identified, or the probability of an event occurring is unknown (e.g., tax changes, regulatory changes, technological change). One method of risk mitigation includes sensitivity analysis, while Monte Carlo simulations and scenario analysis are used to evaluate uncertainty (Salci and Jenkins, 2016). Sensitivity analysis first begins as a spreadsheet model of project inflows and outflows (Salci and Jenkins, 2016). Estimates are used for input variables (Sacli and Jenkins, 2016). Once the spreadsheet model is complete, the next step is to carry out the sensitivity analysis (Sacli and Jenkins, 2016). The sensitivity analysis consists of altering the input variables and recording the output variables as they change (Sacli and Jenkins, 2016). "After defining those variables most likely to have a major impact on outcomes, sensitivity analysis is conducted to test their expected impact on the variability of outcomes." (Sacli and Jenkins, 2016). A way of mitigating uncertainty is by using Monte Carlo simulations (Sacli and Jenkins, 2016). According to Sacli and Jenkins (2016), a Monte Carlo simulation is "a form of sensitivity analysis in which outcomes are calculated using input values based on probability-weighted distributions. The technique simulates a large number of draws from the given distributions of input variables in order to establish the resulting distributions of outcomes." The Monte Carlo simulation must accurately capture the underlying intervention's costs and benefits, along with the probability of the distribution of risk variables being accurate for it to correctly model (Sacli and Jenkins, 2016). Specifically, it is used to model uncertain inputs, such as the price of crude oil in the future through probabilistic means (Sacli and Jenkins, 2016). The last way of mitigating uncertainty offered by Sacli and Jenkins (2016) is scenario analysis. Scenario analysis is the process of comparing an "average expectation with one or other scenarios" (Sacli and Jenkins, 2016). This process involves "a best case (or optimistic case), in which the discounted net resource flows will be better than base-case expectations, and a worst-case (or pessimistic case), in which discounted resource flows will be worse than base-case expectations." Sacli and Jenkins (2016) state, "The main advantage of the scenario analysis model is that it allows relationships between different project variables to be explored– of particular help, for example, when evaluating alternative policy options or regulatory proposals for government intervention." The UK, Australia, EU, France, and the US all suggest using sensitivity analysis, scenario analysis, and Monte Carlo simulations to help mitigate risk and uncertainty (albeit with slightly different recommendations) (Sacli and Jenkins, 2016).

The Optimality Problem Despite Attempts to Manage It

Despite uncertainty being managed, it remains a significant issue. Examining the first method to manage risk, specifically sensitivity analysis, it only looks at the relationship between two variables, an input and an output, and the relative "sensitivity" of the output to the input (Sacli and Jenkins, 2016). This does nothing to resolve uncertainty as it pertains to the optimality problem. It does not provide clarity on exactly how many resources to allocate to any given analysis to achieve the greatest benefit. Sensitivity analysis cannot provide any additional information on future benefits or costs from waiting and the most optimal time to wait. Next, let us examine the first method to lessen the uncertainty of a cost-benefit analysis, Monte Carlo simulations. Monte Carlo simulations can provide estimated results for uncertain variables as well as calculate a net economic benefit in monetary terms in various trials in a given simulation (Sacli and Jenkins, 2016). For instance, Sacli and Jenkins (2016) run a simulation on an amendment for renewable fuels. The proposal generates a net economic benefit, and each trial gives an estimated net economic benefit (Sacli and Jenkins, 2016). While this can assist with uncertainty in the best of conditions, it still does not resolve the optimality problem. The Monte Carlo simulation example by Sacli and Jenkins for the Canadian government's proposal for an increase in average renewable fuel content in gasoline by 5% to reduce greenhouse gas emissions does indeed reduce uncertainty within the scope of the individual proposal. However, what about an alternative proposal being more optimal, all things considered? For instance, instead of increasing it by 5% for all usage of gasoline, what about a 5% increase for just one, maybe two sectors listed (Sacli and Jenkins, 2016) in Table 3 (going on to analyze every possible combination of a 5% increase)? How about a proposal of a 5% increase in biofuel in gasoline only for agricultural use and a 15% increase in photovoltaic solar for energy production? Further, we could even compare using concentrated solar plants instead of photovoltaics while also analyzing each subtype of concentrated solar plants, such as parabolic troughs and solar power towers. Another example by Budowle et al. (2022) shows the usage of Monte Carlo simulations. When comparing swabs for assault victims, there are a variety of options. Budowle et al. (2022) utilize a Monte Carlo simulation to see whether the increase in the identification of offenders was worth the increased cost of a new nylon swab. It was determined that "A simulation approach to analyze benefits and risks enables better use of extant data, obtains more realistic outcomes, and provides better conveyance of the uncertainty associated with the input data." (Budowle et al., 2022). While the results of this analysis compared with a traditional cost-benefit analysis are promising, they are still subject to the uncertainty problem. Budowle et al. (2022) accounted for general uncertainty in cost inputs but did not account for the costs and benefits of waiting for new information regarding new developments in swabs nor in general genetic identification. How do we know that we couldn't realize greater benefits from waiting until the nylon swab becomes cheaper, even if at a higher cost of police work and worse accuracy? It could in theory, be cheaper to wait until the proposed nylon swabs become cheaper, even if there is a temporary disadvantage in waiting. While Monte Carlo simulation helps with uncertainty with inputs, in these examples, it was not shown to reduce any uncertainty about future information that could result in a more optimal decision. These various hypothetical regulations all wanting to achieve the same thing can increase in granularity further to get a truly mathematically optimal solution to the original proposal. However, the mathematical combinations to make a truly optimal solution are likely extremely numerous and increase proportional to the granularity of each input. They are so numerous that analyzing each individual proposal will result in so many resources being used that any benefit would have likely been outweighed by the costs of the analysis alone. In addition, a quest for true optimality can escalate to a disproportionately complicated analysis where there is no defined limit on the scope of analysis. This eventually leads to little progress being made in terms of action in any reasonable time frame.

Quasi-Option Value

The most relevant tool to address the uncertainty problem of cost-benefit analysis is quasi-option value. Quasi-option value is a tool used to evaluate the value gained from delaying a decision in cost-benefit analysis where the action committed to would be irreversible (Atkinson et al., 2006). An example is deciding to convert a forested area to farmland, where between two time periods labeled 0 and 1 we will decide whether to convert the area or preserve it based upon anticipating the magnitude of information gathered in both periods (where period 1 is the future) (Atkinson et al., 2006).

> "By converting now, certain benefits of D_0 are secured (D_0 and D_1 can be thought of as present values). By preserving now, there is a conservation value of V_0, plus an uncertain conservation value of V_1 in period 1. Keeping the analysis simple, let these uncertain values in period 1 be V_{high} and $V_{low.}$ V_{high} might correspond to some very valuable genetic information in the forest. V_{low} would arise if that information turns out to be very much less valuable. Let the probabilities of Vhigh and Vlow be p and (1- p), respectively. The expected value (i.e., probability weighted) of preservation benefits (EP) in both periods, arising from the decision to conserve now, is therefore:
>
> $EP = V0 + pVhigh + (1 – p)Vlow$ [10.1]
>
> A moment's reflection shows that if the forest is converted in 0, the expected value of development benefits will be the same as the certain value of the development benefits:
>
> $ED = D0 + D1$ [10.2]
>
> If the decision to preserve or develop has to be taken now, then a simple comparison of [10.1] and [10.2] will suffice. Thus, the forest would be developed if:
>
> $ED > EP$, or, $[D0 + D1] > [V0 + pVhigh + (1-p) Vlow]$ [10.3]" (Atkinson et al., 2006).

There are significant issues related to quantifying costs and future benefits associated with waiting that undermine the utility of quasi-option value. To begin, quantifying costs and benefits associated with waiting for future information associated with a decision could prove to be immensely challenging. Knowing the entire scope of future information and by which time periods it will arrive for the sake of an optimal decision is simply infeasible. On top of knowing when information could arrive, one also has to quantify the cost of waiting and the benefit of receiving the new information. Atkinson et al. (2006) nor Boardman et al. (2006) give any kind of methodology for quantifying the cost of waiting. Additionally, future benefits from information gained in future time periods are usually crude in nature and rough estimates at best.

Another issue with quasi-option value is a lack of results that validate its utility. According to Atkinson et al. (2006), "Further study is needed in the environmental context to see if similar results hold. Examples to date are limited." Similarly, Boardman et al. (2006) do not provide any data regarding the utility of quasi-option value despite a number of decades passing since the original quasi-option value theory proposal. The quasi-option value is not exempt from the cost-benefit analysis paradox I have proposed. Quasi-option value in no way provides a methodology such that we can positively identify an optimal point of analysis relative to the time and resources given. This is especially clear when we look at the examples provided by Atkison et al. (2006) as well as by Boardman et al. (2006); neither publication gives examples that span more than a few periods, even though theoretically, there could be much longer time horizons that could see much greater benefits to costs. The paradox of cost-benefit analysis has an interesting implication. If one cannot achieve optimality with certainty, then it might be advisable to disregard doing any kind of cost-benefit analysis at all. In the attempt to achieve an optimal result, one can have an infinite time horizon dedicated to conducting a cost-benefit analysis with respect to information later discovered that can significantly benefit oneself. With a lack of empirical data regarding protracted quasi-option value over long time periods, it might be reasonable to act without conducting a cost-benefit analysis at all. Even the very act of analyzing whether to perform a cost-benefit analysis at all, that is, meta-cost-benefit analysis, is bound by this paradox. If much greater results can be achieved with much less effort, it would be advisable not to conduct any protracted cost-benefit analysis or even commit to any effort at all by not doing one in the first place.

DISCUSSION

The Current State

It is worth mentioning that despite such a conundrum, cost-benefit analysis can be conducted for a net benefit both in pure principle and in practice, as evidenced by its continued usage by governments to evaluate public projects (Edge, 2021). In terms of pure principle, despite the uncertainty of where the most optimal decision may be, one can still realize a better position than they were in before after doing a cost-benefit analysis (even with sunk costs of the analysis accounted for).

Going back to the previous example of choosing financial products to buy and sell to maximize wealth, we will find that with little research, one can potentially advance one's financial position. Let's say we want to utilize cost-benefit analysis to quickly choose a good buying and selling strategy. Beating the market means achieving greater annual returns than the S&P 500 index (Fontinelle, 2022). According to Malkiel (2003), "Throughout the past decade, about three-quarters of actively managed funds have failed to beat the index." Moreover, Malkiel (2003) says, "Managed funds are regularly outperformed by broad index funds, with equivalent risk. Moreover, those funds that produce excess returns in one period are not likely to do so in the next." Just from this light research, we can see that buying into the S&P 500 fund is unlikely to be matched by even industry professionals whose sole job is to maximize returns with asset classes (Malkiel, 2003). We can then conclude that the benefits versus costs of buying into the S&P 500 compared to actively managing a fund are overwhelmingly in favor of the former option based on returns alone. When we investigate risk-adjusted returns, the difference becomes even more stark (Malkiel, 2003). This example demonstrates how, despite the paradox of cost-benefit analysis, one can still realize tangible benefits from conducting one.

Current studies of the direct impact of cost-benefit analysis were difficult to find, particularly in terms of return on investment. Volden (2019) studied the general characteristics of public project cost-benefit analyses to examine quality in the selected pool. In addition, factors impacting quality were examined (Volden, 2019). Volden (2019) found that in the studied public project cost-benefit analyses, the analyses were of good, comprehensive quality. Interestingly, it was found that factors leading to a useful cost-benefit analysis were supplementary information about sustainability being reported, analyses being standardized across projects, non-monetized impacts being included, uncertainty being properly analyzed, analyses not being biased, and independent reviews to secure accountability (Volden, 2019). Quasi-option value was briefly discussed by Volden (2019) as a method to reduce uncertainty, but no elaboration was given. Dehnhardt et al. (2022) found that in a sample of municipal actors, the perception of cost-benefit analysis was positive, with it being used to determine whether to pursue an urban green water drainage initiative. Dehnhardt et al. (2022) state that our study confirmed that building economic knowledge is a crucial factor in CBA's usefulness. A lack of knowledge and insufficient economic training are said to be important barriers to using economic valuation results to support political decisions." Considering the lack of literature, It might be recommended that future studies examine the return on investment in terms of time and money, as well as opportunity cost, to conduct a cost-benefit analysis. This type of analysis could help more clearly identify utility despite the paradox identified in this paper.

CONCLUSIONS

Cost-benefit analysis remains a common tool to provide insight into various alternatives while supporting rational decision-making. However, it is essential to acknowledge the limitations of such a tool. Some of the established shortcomings are difficulty quantifying subjective human elements such as value, discounting for future benefits and costs, and being impartial in environmental regulation settings. In addition, it suffers from both risk and uncertainty in calculations and assumptions. While there are ways to account for risk and uncertainty through sensitivity analysis, Monte Carlo simulations, scenario analysis, and quasi-option value, these tools are not enough to remedy the uncertainty problem. The uncertainty problem remains a significant issue with respect to optimality. In this essay, I identify a paradox of cost-benefit analysis found in the uncertainty problem: one cannot achieve an optimal decision with any certainty such that analysis and any recursive analysis can continue infinitely. One can never know what the most optimal decision is despite cost-benefit analysis serving as a tool to figure out the most economically optimal decision relative to costs and benefits. However, despite the uncertainty problem, cost-benefit analysis could still potentially be a tool of utility.

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