Teaching and Educational Methods

Benefit-Cost Analysis Decision Criteria: Reconciling Conflicting Advice

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JEL Codes: A20, D61, G11, H43, O22
Keywords: Benefit:cost ratio, cost-benefit analysis, decision making, internal rate of return, net present value, prioritization

Abstract
Net present value (NPV), benefit: cost ratio (BCR), and internal rate of return (IRR) are fundamental concepts of benefit-cost analysis (BCA), providing helpful criteria for decision making about investments. However, textbooks on BCA are remarkably inconsistent in the advice they provide about which of these decision criteria should be used, potentially creating confusion among teachers and students. We present an existing conceptual framework that clarifies which of the three criteria should be used in particular decision contexts, depending on whether the projects in question are independent or mutually exclusive, and on whether the projects are resourced from a fixed pool of funds. The framework reveals that some of the advice provided by particular textbooks is incorrect, and some is correct only in certain decision contexts. Some books dismiss the use of BCR in general, but we show that it is the preferred criterion in certain cases and clarify how it should be calculated. The argument that BCRs can be manipulated by moving costs between the denominator and the numerator is fallacious. Recognizing that these decision criteria should not be applied mechanistically, we argue that the framework presented has the potential to improve decision making in many cases.

1 Introduction

The idea of comparing benefits and costs of a project or investment has a long history. Even before benefit-cost analysis (BCA)[1] was established as a distinct method of analysis, decision makers down the millennia have presumably weighed up the benefits and costs of their options in at least an intuitive way. Then in 1936, the Flood Control Act in the United States stated that projects should be supported "if the benefits to whomsoever they accrue are in excess of the estimated costs," and this kicked off the widespread use of BCA to assess publicly funded projects (Pearce 1983). In 1950, the U.S. Federal Inter-Agency River Basin Committee produced the *Green Book*, which laid down guidelines for comparing costs and benefits (Pearce 1983). Since then, BCA has flourished, and today it is used around the world in a wide variety of contexts, including to assess projects to build new transport infrastructure, conduct public health campaigns, expand agricultural production, or introduce environmental regulations. There are dozens of textbooks available for students of the technique, and many governments around the world have produced their own BCA guidelines, sometimes for specific contexts, such as transport, and sometimes general.

In BCA, a core issue is the use of a set of standard criteria to summarize results and guide decision making. Different textbooks present different decision criteria, but most include net present value (NPV), benefit: cost ratio (BCR), and internal rate of return (IRR).

[1] Or, equivalently, cost-benefit analysis (CBA).

The three decision criteria are conceptually simple. The NPV is calculated as

$$NPV = B - C \tag{1}$$

where B is the aggregate present value of the stream of benefits generated by the project, and C is the aggregate present value of the project's costs. We will look at alternative ways to calculate the BCR, but the approach that is most commonly presented in textbooks is

$$BCR = B / C \tag{2}$$

IRR has no unique formula but equals the discount rate at which the NPV = 0 or BCR = 1.

Numerical Example

The Department of XYZ is considering whether to fund three projects. The benefits and costs of the projects are shown in Table 1, together with their NPV, BCR, and IRR, calculated as described above.

Table 1: Benefits and Costs of Three Example Projects

	Year	0	1	2	3	4	5	Present value*	NPV*	BCR*	IRR
Project 1	Benefit	$0	$100	$300	$500	$500	$400	$1,451	$1,080	3.90	78%
	Cost	$200	$200	$0	$0	$0	$0	$372			
Project 2	Benefit	$0	$0	$300	$500	$600	$600	$1,588	$1,216	4.27	70%
	Cost	$200	$200	$0	$0	$0	$0	$372			
Project 3	Benefit	$0	$0	$500	$700	$800	$1,000	$2,381	$1,637	3.20	54%
	Cost	$400	$400	$0	$0	$0	$0	$744			

We reviewed a large number of BCA textbooks and guidelines (see Appendix) and found that, in most respects, they are consistent in the advice they provide. However, their advice on the appropriateness of using the different criteria (NPV, BCR, and IRR) is highly inconsistent, and sometimes in direct contradiction. For example, some textbooks advise their readers to rely primarily on NPV for decision making and to avoid the use of BCR (e.g., Gramlich 1990; Boardman et al. 2018; de Rus 2021). Others encourage the use of BCR, particularly where the task of decision makers is to rank projects subject to a budget constraint (e.g., Layard and Glaister 1994; Fuguitt and Wilcox 1999; Campbell and Brown 2016). Still others prefer IRR over BCR in the budget-constrained scenario (e.g., Gittinger 1972; Brent 2003), conflicting with those who advise against using the IRR at all (e.g., Hanley and Barbier 2009). The potential for confusion is great, and we observe that confusion often continues when students of BCA graduate and start applying the technique.[2]

We aim to clarify these issues for teachers, students, and practitioners. We show that there are different decision contexts within which use of the three decision criteria needs to be considered. We identify some fallacies in the arguments presented in some textbooks and guidelines regarding the appropriateness of using particular decision criteria, particularly the BCR. This leads to clear and

[2] The advice provided in BCA guidelines from public agencies is similarly diverse and contradictory. Some recommend using the BCR to rank projects in the budget-constrained scenario (U.S. Environmental Protection Agency 2010; HM Treasury 2022), some express a general preference for using the NPV over the other two criteria (e.g., Commonwealth of Australia 2006), and some fail to even mention BCR (e.g., Asian Development Bank 2013).

unambiguous rules for when particular decision criteria should and should not be used and, in the case of BCR, how it should be calculated. Thus, there need be no contradictions, or even ambiguity, in the advice given about the standard decision criteria.

2 Conflicting Advice

As noted above, a number of textbooks advise readers to rely primarily on NPV to guide decision making. For example, Boardman et al. (2018, p. 35) say, "we recommend that analysts avoid using benefit–cost ratios to rank policies and rely instead on net benefits [NPV]." Some textbooks fail to even mention BCR as a potential decision criterion (e.g., Marglin 1967; Ray 1984; Dinwiddy and Teal 1996). Arguments presented against the use of BCR include that it can bias decision making toward small-scale projects (e.g., Brent 2017; Boardman et al. 2018) and that it is sensitive to whether costs are included in the denominator or subtracted from the numerator (e.g., Johansson and Kriström 2015; Nas 2018).

On the other hand, the use of BCR is widely supported in other textbooks. Some point out that, for an individual project, the decision criterion NPV > 0 is equivalent to BCR > 1, so that either can be used (e.g., Brent 1998). "It should be clear that when: NPV ≥ 0, then BCR ≥ 1" (Campbell and Brown 2016, p. 48).

Others argue that if there is a limited budget available to fund projects, the way to maximize overall NPV is to rank the candidate projects according to BCR, selecting those projects with the highest BCRs until the budget is exhausted (e.g., Abelson 1979; Nas 2018): "there is the problem of capital rationing, where the correct approach is to select projects in order of their present value per unit of constrained costs until the cost constraint is exhausted" (Layard and Glaister 1994, p. 43).

IRR too is favored by some authors. "The internal rate of return is the best index when there is a capital constraint" (Brent 2003, p. 43) (contradicting the authors cited in the previous paragraph). "When one can consider projects independently, and there are no technical difficulties ... with IRR, the three criteria [NPV, IRR, BCR] are equivalent (one rule implies the other two)" (Brent 1998, p. 32).

The technical difficulties referred to by Brent (1998) are raised by some authors as barriers to the use of IRR: "many projects can generate multiple IRRs from the same data set, so the analyst does not know which to select as the decision-making criterion" (Hanley and Barbier 2009, p. 6), and IRR makes assumptions about income generated by a project that may not be realistic (Renshaw 1957). Even without those technical difficulties, some argue that the scope for using IRR is limited. "There is general agreement that the IRR should not be used to rank and select mutually exclusive projects" (Pearce, Atkinson, and Mourato 2006, p. 73), and IRR "fails generally to maximize present values because … it is biased towards low capital projects" (Abelson 1979, p. 43).

Finally, there is inconsistency in the formula for calculating the BCR. As well as the version in Equation (2), some textbooks (e.g., Bergstrom and Randall 2016; Campbell and Brown 2016) present the following as an alternative formula:

$$BCR = (B - C_o) / C_k \tag{3}$$

where C_o is the aggregate present value of operating costs and C_k is the aggregate present value of capital costs.

With so much inconsistency and so many contradictions, it is not surprising that people get confused.

3 Reconciling the Differences

A key to clarifying the roles of the different decision criteria is recognizing that they each perform better or worse in particular decision contexts. This was established in the 1950s (e.g., Lorie and Savage 1955; Hirshleifer 1958), and the insights that were derived more than six decades ago are still applicable today. Often the contradictions noted above arise because authors have not recognized that different advice is needed in different contexts.

There are two key factors that influence the performances of different decision criteria in BCA. The first factor is whether BCA is being used to inform decisions that are subject to a funding constraint. A typical scenario would be where an organization has an allocated budget of a fixed size from which it will resource a selected subset of projects from a set of candidate projects. The budget is not sufficient to resource all the candidate projects, so prioritization is necessary. This scenario is common, for example, where a government body (national, state, or local) is making decisions about funding many competing projects from a particular funding program. The simplest case is where there is a single funding constraint.

Alternatively, for some decisions it may be considered that there is no binding budget constraint. For a national government, for example, if a project is worth funding, it could be funded by raising taxes or borrowing money.

The second factor is whether the projects being considered are independent. If two projects are independent, then the benefits and costs of each project are unaffected by whether the other project is implemented. For example, a project to reduce traffic congestion in one city and a project to reduce water pollution in a different city would probably be independent. Where projects are not independent, their degree of dependence may vary along a continuum. The simplest case is the extreme one where all the candidate projects are mutually exclusive, meaning that only one out of the set of projects can be funded. An example would be a set of discrete project options, each of which would be implemented on the same piece of land (e.g., a car park, a building, or a garden). If any one of the projects is implemented, the others are automatically ruled out.

4 Context-Sensitive Recommendations

Combining these two factors, in their simplest forms, gives a two-by-two matrix of cases for which recommendations about BCA decision criteria are needed (Table 2). The need to use different decision criteria in the different quadrants of the table was recognized by Lorie and Savage (1955), who provided correct recommendations about each of the four cases.[3] Hirshleifer (1958) also recognized that, “the solutions for optimal investment decisions vary according to a two-way classification of cases. The first classification refers to the way market opportunities exist for the decision-making agency [i.e., budget-constrained versus unconstrained]; the second classification refers to the absence or presence of the complication of non-independent productive opportunities [i.e., independent versus mutually exclusive projects]” (Hirshleifer 1958, p. 342).

For these four quadrants, clear and relatively simple decision criteria are identified. The overarching objective of the decision maker is assumed to be maximization of the total NPV from the investments undertaken.

If there is no constraint on the budget and the candidate projects are independent, there is no project ranking to be done, only a yes-no decision for each project. Each criterion works equally well for that purpose: NPV > 0, BCR > 1, and IRR > the discount rate, are equivalent (Dryden 1962; Prest and Turvey 1965; Schwab and Lusztig 1969), barring “technical difficulties” with IRR (outlined below).

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[3] Their advice for the independent/constrained quadrant went beyond the simplest case, considering nondivisible projects (those which must be funded in full or not at all) and multiple constraints, but Table 2 focuses on the simplest case.

Table 2: BCA Decision Criteria That Maximize Overall NPV

	All projects independent	All projects mutually exclusive
Funding unconstrained	Fund all projects with NPV > 0, BCR > 1, or IRR > discount rate (all are equivalent). No ranking required.	Choose the project with the highest NPV.
Project costs subject to one funding constraint	Rank projects by BCR.	Select the project with the highest NPV that is feasible (does not exceed the funding constraint)

Numerical Example continued.

For the example projects in Table 1, if the projects are independent, and there is no budget constraint, then all three projects are assessed as being worth funding, whichever of the three decision criteria are used. The three NPVs ($1,080, $1,216, and $1,637) are all greater than zero; the three BCRs (3.90, 4.27, and 3.20) are all greater than 1.0, and the three IRRs (78 percent, 70 percent, and 54 percent) are all greater than the discount rate of 5 percent.

The criticisms that are sometimes made of BCR do not apply in this case. Although the BCR can be altered by moving costs between the denominator and the numerator, this does not affect whether the BCR is greater than one, which is the relevant decision criterion. And although lower-cost projects may be favored if projects are ranked using BCR relative to NPV, the ranking of projects is irrelevant because the decision rule is to fund *all* projects with NPV > 0, BCR > 1, or IRR > discount rate. Campbell and Brown (2016, p. 48) proposed that "when it comes to comparing or ranking two or more projects, again assuming no budget constraint, the BCR decision-rule can give incorrect results." However, this advice is not relevant—if there is no budget constraint, there is no need to rank independent projects, and the decision rule BCR > 1 does not give incorrect results.

Under a constrained budget, ranking independent projects by BCR is superior to ranking by NPV, even though the overarching objective is to maximize the total NPV (Lorie and Savage 1955; Hoskins 1974).

Numerical Example continued.

Consider the three project options offered in Table 1. Suppose that all the costs for these potential projects would be drawn from a particular pool of funds, and that the pool contains $800. If we rank the projects by NPV, Project 3 is preferred, and the total NPV from the investment is $1,637. However, if we rank them by BCR, Projects 1 and 2 are preferred, and both can be afforded within the $800 budget constraint. The total NPV in that case is $1,080 + $1,216 = $2,296, so this is clearly the better ranking method. For a budget of $800, ranking by IRR also leads to funding Projects 1 and 2 as it provides the same ranking, and therefore the same total NPV as does ranking by BCR.

Now suppose that the budget is only $400. For the sake of this example, assume that if a project is partly funded, its benefits are scaled down linearly in proportion to the level of funding: half the funding leads to half the benefits. Now ranking by NPV leads to funding half of Project 3, with NPV of $1,637 / 2 = $819. Ranking by BCR results in funding Project 2, with NPV of $1,216, and ranking by IRR results in funding Project 1, with NPV of $1,080. Ranking by BCR is the best option.

Consider whether the common criticisms of BCR are applicable in this decision context. The criticism that ranking projects using BCRs biases decisions toward supporting small projects (e.g., Commonwealth of Australia 2006) seems potentially relevant, since ranking is required to prioritize the projects. However, the example in Table 1 shows that the relatively favorable assessment of projects with smaller costs is not a bias in this scenario—it is an accurate reflection of the relative merits of the competing projects when there is a budget constraint. Indeed, a more pertinent observation in this case would be that NPV is biased toward supporting large projects.

The other criticism is that BCR is an unreliable decision metric because its magnitude is sensitive to how costs are allocated between the numerator and the denominator of the BCR, and the allocation is arbitrary. For example, Lund (1992) provides a numerical example in which the BCR of a project ranges from 1.38 to infinity depending on which of a set of costs are added to the denominator or subtracted from the numerator. He concludes that this "demonstrates some particularly severe problems of the benefit-cost ratio." While it is true that the allocation of costs between the denominator and the numerator does affect the BCR, for the independent/budget-constrained case, it is not correct that the allocation is arbitrary. Given our objective of maximizing overall NPV, the appropriate allocation of costs is clear: the denominator should contain all costs that are subject to the constraint (i.e., they are drawn from the fixed available pool of funds), and all other costs should be subtracted from the benefits in the numerator. No other allocation of costs results in a ranking of the projects that would maximize the overall NPV. The argument that BCRs are unreliable because the allocation of costs is arbitrary is a fallacy for this decision context.

Thus, the correct formula for the BCR for ranking projects in the independent/budget-constrained case is:

$$BCR = (B - C_u) \, / \, C_c \tag{4}$$

where C_u is the aggregate present value of unconstrained costs, and C_c is the aggregate present value of constrained costs. Unconstrained costs potentially include project implementation or operating costs drawn from sources other than the pool of funds being allocated by the decision maker, in-kind costs, the excess burden of taxation, and any unintended negative impacts of the project.

This insight into the correct calculation of BCR was recognized by Bain (1960): "the government should, if constrained as to budget for capital outlay or operations or both combined, rank and choose among investment opportunities [based on] a maximum excess [i.e., benefit] net of unconstrained costs, over constrained costs." Since then, it has rarely been fully recognized and correctly expressed in BCA textbooks or government guidelines. Most authors do not discuss how to rank projects if only some of the project costs are from a constrained pool of funds, with Layard and Glaister (1994) one of the rare exceptions (on p. 43). The formulation in Equation (3) with capital costs in the denominator and operating costs in the numerator (e.g., Campbell and Brown 2016) is correct if all capital costs, and only capital costs, are subject to a budget constraint.

Numerical Example continued.

Suppose that the costs shown in Table 1 would be borne by the Department of XYZ and are subject to a budget constraint of $400, but that there are additional costs borne by others that are not subject to any budget constraint, as shown in Table 3. With these costs and the benefits shown in Table 1, the overall NPVs are $758 for Project 1, $785 for Project 2, and $962 for Project 3. Using the BCR formula in Equation (2) (all costs in denominator), the BCRs are 2.09 for Project 1, 1.98 for Project 2, and 1.68 for Project 3. Using the BCR formula in Equation (4) (constrained costs in denominator), the BCRs are 3.04 for Project 1, 3.11 for Project 2, and 2.29 for Project 3.

Ranking the projects using Equation (2) results in XYZ choosing to fund Project 1, with a resulting NPV of $757.94, but this is not the best decision because it fails to account for the fact that only some of the costs are drawn from the constrained budget. Ranking the projects using Equation (4) results in Project 2 being preferred, giving a higher NPV of $784.55. In general, Equation (4) performs best for ranking projects when only some of the costs are constrained.

Table 3: Revised Costs of the Three Example Projects, Consisting of Costs to the Department of XYZ (Subject to a Budget Constraint of $400) and Other Costs (Not Subject to a Budget Constraint)

	Year	0	1	2	3	4	5	Present value
Project 1	Cost to XYZ (constrained)	$200	$200	$0	$0	$0	$0	$372
	Other cost (unconstrained)	$0	$0	$100	$100	$100	$100	$322
Project 2	Cost to XYZ (constrained)	$200	$200	$0	$0	$0	$0	$372
	Other cost (unconstrained)	$0	$0	$500	$0	$0	$0	$432
Project 3	Cost to XYZ (constrained)	$400	$400	$0	$0	$0	$0	$744
	Other cost (unconstrained)	$0	$0	$400	$400	$0	$0	$675

Note: In the BCRs reported in the text, the benefits are the same as in Table 1. Discount rate = 5 percent.

There are, however, limits to the applicability of the decision rule to rank by BCR in the independent/budget-unconstrained scenario. It strictly holds only if *all* the projects under consideration are independent, and if there is only a single constraint affecting the decisions—one fixed pool of funds from which funds are drawn. Also, it assumes that the marginal project (the one with the lowest BCR that lies partly within the budget envelope) is continuously scalable and that benefits scale in proportion to costs. Situations where these conditions are not met may require a constrained optimization algorithm (e.g., integer programming, nonlinear programming) to identify the optimal decision (Dryden 1962), or an acceptance that ranking by BCR provides an approximately optimal solution. If optimization is used, the recommendation from Table 2 that most closely matches the actual decision context could be used as a starting value, if required by the optimization algorithm.

If the candidate projects are mutually exclusive, the decision rule is straightforward: choose the project with the highest NPV that does not exceed the funding constraint (if there is one). This is the situation where the criticism that BCR is biased toward smaller projects is valid, and it should not be used. For similar reasons, choosing the mutually exclusive project with the highest IRR may also favor relatively small projects and lead to inferior decisions in this context.

Numerical Example continued.

If the projects described in Table 1 are mutually exclusive, it means that only one of them can be chosen for funding. In that case, the preferred project is the one with the highest NPV, Project 3, which produces an NPV of $1,637. Ranking by BCR would indicate support for Project 2 as it has the highest BCR of 4.27, but it delivers an NPV of only $1,216. Ranking by IRR would lead to support for Project 1, with the highest IRR of 78 percent but the lowest NPV of $1,080.

The recommendation to use NPV for decisions about mutually exclusive projects only strictly holds if *all* of the projects under consideration are mutually exclusive. If the projects under consideration are a mix of mutually exclusive projects and independent or partially dependent projects, none of the simple decision criteria will lead to ideal decision making. A constrained optimization algorithm would be needed.

4.1 Issues with IRR

IRR appears only in the independent/unconstrained-budget quadrant of Table 2, in which it is recognized that the decision rule IRR > discount rate can be equivalent to NPV > 0 and BCR > 1. There is no decision context for which the use of IRR leads to superior decisions compared with the other two criteria, and in three of the four contexts, it is inferior. Thus, even in the absence of any technical difficulties, there is no advantage in using IRR to guide decision making.

How serious are the technical concerns that have been raised about IRR? One concern is that the way that the IRR is calculated implies that positive cash flows will be reinvested at the IRR (Renshaw 1957), and this may be unrealistic.

Numerical Example continued.

Project 1 in Table 1 has an IRR of 78 percent, and it has $500 net benefits in year 3. The implicit assumption in calculating the IRR is that the $500 generated in year 3 will be invested at a 78 percent annual rate of return for the remainder of the evaluation period. It may be that there are no other investment opportunities available that offer a 78 percent rate of return. Perhaps the best available rate of return is 5 percent in a bank account, in which case IRR overstates the overall performance of the investment.

On the other hand, if we restrict the use of IRR to the independent/unconstrained-budget case, this issue is no longer a concern because the only question is whether the IRR exceeds the chosen discount rate. The discount rate should in principle reflect realistic investment opportunities.

The possibility of unrealistic reinvestment rates would be of a concern if IRR were used to rank competing independent projects that are subject to a budget constraint, or to rank alternative mutually exclusive projects. As noted earlier, its use in the latter context is likely to bias decision making toward smaller projects that are less beneficial overall. If ranking independent projects, as well as the reinvestment-rate issue, IRRs are unable to account for the fact that some costs are constrained and others unconstrained, leaving BCR calculated according to Equation (4) as the preferred ranking criterion.

The second and more frequently raised technical concern is that a project can have multiple valid IRRs, leaving decision makers uncertain about which IRR to use for decision making. Multiple IRRs are possible (though not certain) if the stream of net benefits for a project has multiple changes of sign over time (e.g., from negative to positive and back to negative). This is not a concern with most projects, but it can occur. “In real life there may of course be few projects for which the net returns stream changes sign more than once, except in industries where there may be heavy terminal costs (such as filling in mines or decommissioning nuclear power plants and so on)" (Layard and Glaister 1994, p. 43).

Numerical Example continued.

Consider a project with the following stream of net benefits (benefits minus costs in each year), including a large terminal cost: –65, 25, 50, 75, 120, –220. Net benefits change from negative to positive and back to negative. Given these numbers, the relationship between discount rate and NPV is shown in Figure 1. There are two discount rates at which the NPV = 0, and hence two valid IRRs: 9 percent and 32 percent.

Having multiple changes of sign in the stream of net benefits does not necessarily result in multiple IRRs. Figure 2 shows the equivalent graph for a slightly modified stream of net benefits: –65, 25, 50, 75, 120, –200. In this case, there is only one IRR, and the usual interpretation is valid.

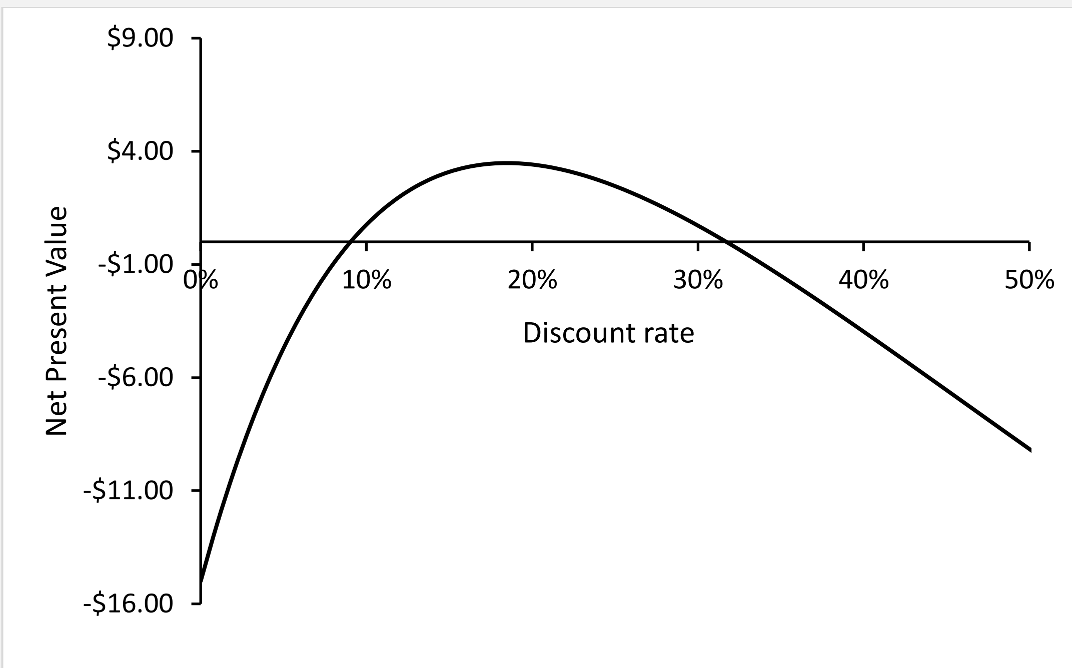

Figure 1: NPV versus Discount Rate for the Stream of Net Benefits, –65, 25, 50, 75, 120, –220

Viewing Figure 1 clarifies how the two IRRs should be interpreted for decision making. If the chosen discount rate is between the two IRRs, the NPV is positive and the project is desirable. Applying the usual decision criterion (IRR > discount rate) to the lower IRR would be misleading, and even applying it to the higher IRR could be misleading (if the discount rate is below 9 percent). Thus, if there are multiple IRRs, it is not a matter of deciding which of them to use; the issue is whether the discount rate lies between two IRRs that bound a positive section of the NPV curve.

Given that spreadsheet software provides only one IRR and does not indicate whether there are multiple IRRs, users of IRR need to take care (Rosbaco 1999; Hazen 2003). They probably need to create a graph like Figures 1 and 2 to check whether there are multiple IRRs within a realistic range of discount rates, and if so, use the graph to assist with their interpretation (Bey 1998). Given the level of knowledge and effort required, basing decisions on NPV or BCR is probably more convenient.

Figure 2: NPV versus Discount Rate for the Stream of Net Benefits, –65, 25, 50, 75, 120, –200

5 Limits of the Standard Criteria

The four decision scenarios presented in Table 2 represent specific decision contexts for which the advice to use one or more of the standard decision criteria can be made with confidence. However, they are, in a sense, extreme cases. In practice, most real decisions are made in circumstances that do not exactly match any of these four contexts. For example, the candidate projects might be a mix of independent, partially dependent, and mutually exclusive projects. There might be more than one constraint on the selection of projects, such as a constraint on capital costs and a different constraint on operating and maintenance costs, or a constraint on the availability of a nonfinancial resource. Projects might not be scalable or might scale nonlinearly.

In these cases, no simple decision criterion can be assured of generating an optimal set of decisions. Depending on how similar the real decision-making context is to these idealized contexts, it may be judged that one of the contexts in Table 2 is sufficiently close for a particular decision criterion to provide approximately optimal results. If that is not the case, an alternative is to develop a constrained optimization model that fully captures the specific decision context.

In practice, we rarely observe the latter happening. Most commonly, in cases where BCA results are directly utilized in decision making, decision makers select the decision criterion that they judge to be most suitable and base their decisions on that, often with adjustments for other factors that have not been captured in the BCAs. Given the time and resource constraints that typically apply to decision making, this seems a pragmatic approach.

However, given the inconsistencies and contradictions we have identified in BCA textbooks and guidelines, we wonder how often decision makers are relying on decision criteria that are not the best fit for their decision context. For example, we have observed decision makers using NPV or IRR to rank independent projects subject to a budget constraint, or BCR to select from a set of mutually exclusive projects, all of which are inconsistent with Table 2. We recommend that decision makers use the framework in Table 2 as the starting point in their deliberations.

6 Conclusion

Every BCA textbook and guideline describes how to calculate a NPV and most describe BCR and IRR. They also typically provide advice on which of these decision criteria should be used, either at all or in particular contexts.

Unfortunately, as we have seen, this advice is highly inconsistent between textbooks, which unavoidably means that some of it is incorrect. We have reconciled the conflicting advice using an existing framework that describes different decision contexts and the decision criteria that perform best in those contexts. Only a small minority of existing textbooks use this framework, or something close to it (e.g., Sassone and Schaffer 1978; Pearce and Nash 1981; Layard and Glaister 1994; Fuguitt and Wilcox 1999; Campbell and Brown 2016).

We have explained the reasons for preferring particular decision criteria in each context, and in the process debunked some widely believed fallacies, particularly regarding BCRs. We have highlighted the correct formula for calculating the BCR when the costs are partially drawn from a constrained budget—a formula that is absent from most textbooks.

The insights presented here are relevant to decision making about public projects, programs, and policies of any type, in any country. We recognize that when BCA results are used to inform real decision making, a pragmatic approach is often needed. Nevertheless, we believe that wider awareness and application of the decision criteria framework (Table 2) would help to improve the quality of many decisions about public investment in policies, programs, and projects.

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Acknowledgments: The authors thank Michael Burton and Graham Marshall for their participation in debates and discussions that ultimately led to this paper.

Appendix: The Benefit-Cost Analysis Resources Reviewed

This table lists the textbooks and guidelines reviewed in the preparation of this paper.

Table A1. Benefit-Cost Analysis Resources

Reference	Resource Type
Abelson, P. 1979. *Cost Benefit Analysis and Environmental Problems*. Farnborough UK: Saxon House.	Textbook
Asian Development Bank. 2013. *Cost-Benefit Analysis for Development: A Practical Guide*. Manilla, Philippines.	Guideline
Atkinson, G., N.A. Braathen, B. Groom, and S. Mourato. 2018. *Cost-Benefit Analysis and the Environment: Further Developments and Policy Use*. Paris: OECD Publishing.	Guideline
Bergstrom, J.C., and A. Randall. 2016. *Resource Economics: An Economic Approach to Natural Resource and Environmental Policy,* 4th ed. Northampton MA: Edward Elgar.	Textbook
Boardman, A., D. Greenberg, A. Vining, and D. Weimer. 2018. *Cost-Benefit Analysis: Concepts and Practice,* 5th ed. Cambridge UK: Cambridge University Press.	Textbook
Brent, R.J. 1998. *Cost-Benefit Analysis for Developing Countries.* Northampton MA: Edward Elgar.	Textbook
Brent, R.J. 2003. *Cost-Benefit Analysis and Health Care Evaluations.* Northampton MA: Edward Elgar.	Textbook
Brent, R.J. 2006. *Applied Cost-Benefit Analysis,* 2nd ed. Northampton MA: Edward Elgar.	Textbook
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