The Benefit: Cost Ratio

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The information to calculate the Benefit: Cost Ratio (*BCR*) is collected in the course of completing the Project Assessment Form (PAF). The variables that feed into calculation of the Benefit: Cost Ratio are mostly specified as proportions, and are included in the Index multiplicatively. Within this approach, there is no need to provide weights for each variable (as one would do in a Multi-Criterion Analysis). Indeed, given the way the formula is structured, introducing weights into the process would conflict with the logic of the approach. The BCR is broadly consistent with the "Project Prioritisation Protocol" of Manoney, Joseph and Possingham (2009)[1], although the BCR is more detailed and includes more elements.

The *BCR* is calculated as follows:

$$BCR = \frac{(VPPB \times A \times (1 - RF) \times DF}{TPVEPC} \tag{1}$$

where

VPPB = the value of potential project benefits, assuming that that the required works are fully adopted, and that there are no risks to project success and no time lags.

A = the proportion of required adoption of new works and actions that is expected to be achieved by the project. By definition, this is a proportion. Given the structure of equation (1), it is assumed that benefits are proportional to the level of adoption. If full adoption is assured (e.g., the required works and actions will be undertaken by the organisation running the project) then $A = 1$. If adoption must be undertaken by private landholders or by another organisation, $A < 1$ would often be expected.

RF = the risk of failure of the project, so $(1 - RF)$ repesents the probability that the project will not fail.

DF = the discount factor for the time lag on benefits. Consistent with standard economic theory, the discount factor is calculated as $DF = 1/(1 + r)^L$, where L = time lag until the majority of anticipated benefits from the project occur (years) and r is the real discount rate, assumed to be 5%. The way that discounting of benefits enters the formula in equation (1) is correct for a situation where the benefits of the project begin after a certain time lag and are then sustained forever.

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[1] Joseph L.N., Maloney, R. and Possingham, H.P. (2009). Optimal allocation of resources among threatened species: a project prioritization protocol, *Conservation Biology* 23: 328-338.

TPVEPC = total present value of expected project costs, in dollars. As with the benefits, future costs should also be discounted to their present values to make them comparable in a logically consistent way.

Since *A*, *RF* and *DF* are all proportions or probabilities, they must be multiplied into *VPPB*. If *VPPB* is measured in dollars, then, since *A*, *RF* and *DF* are all proportions or probabilities, the numerator of equation (1) is also in dollars, and represents the expected value of project benefits. Note that equation (1) departs from the formula most commonly used in Multi-Criteria Analysis, where the variables are multiplied by subjectively determined weights, and added up to provide an index of benefits. That weighted additive approach would not accurately reflect the benefits calculated by equation (1).

In INFFER, the variables of equation (1) are further broken down as follows.

$$VPPB = V \times W \times 20 \qquad (2)$$

where

V = the value of the environmental asset, assuming that the project is immediately successful.

W = multiplier for impact of works on asset value, as a proportion of *V*. What proportion of the asset's value would be protected or improved as a result of the project, assuming that it is immediately successful?

V is quantified using a scoring system, where each point represented a value of $20 million, hence the inclusion of 20 in equation (2) to express *VPPB* in millions of dollars. This means that the benefits index (the numerator of equation (1)) is measured in millions of dollars.

$$RF = 1 - F \times B \times P \times G \qquad (3)$$

where

F = multiplier for technical feasibility risk (probability that the project will not fail due to problems with technical feasibility)

B = multiplier for risk of adoption of adverse practices (probability that the project will not fail due to adverse adoption)

P = probability that socio-political factors will not derail the project, and that required changes will occur in other institutions

G = probability that essential funding subsequent to this project will be forthcoming (e.g. this project may be the first phase in a longer project, or ongoing payments to landholder may be needed to retain the benefits generated by this project).

$$TPVEPC = C + \mathrm{PV}(M+E) \times G \qquad (4)$$

where

C = short-term cost of current project ($ million in total, over the three-year life of the project)

M = annual cost of maintaining outcomes ($ million per year, beyond the immediate project).

PV(*M+E*) = present value function to convert a stream of future annual maintenance costs and compliance costs (assumed constant in real terms) to a total equivalent present-day value (in $ millions). Assuming that the real discount rate is 0.05 and that the time frame for paying these costs is 20 years, commencing in year 4, *PV*(*M*) = 10.7 x (*M+E)*. The term *G* enters this equation as well, as it represents the probability that the costs *M* and E will actually be borne.

Substituting equations (2), (3) and (4) into (1), we get:

$$BCR = \frac{V \times W \times A \times F \times B \times P \times G \times DF \times 20}{C + PV(M + E) \times G} \tag{5}$$

where

V = value of the asset

W = multiplier for impact of works

F = multiplier for technical feasibility risk

A = multiplier for adoption

B = multiplier for adverse adoption

P = multiplier for socio-political risk

G = multiplier for long-term funding risk

DF_B = discount factor function for benefits, which depends on *L*

L = lag until benefits occur (years)

C = short-term cost of project

PV = present value function

M = annual cost of maintaining outcomes from the project in the longer term.

E = compliance costs for private citizens, if the project involves enforcement of regulations.

Note that, other than *V*, all variables in the numerator lie between zero and one. This is the case for *W* and *A* because they are expressed as proportions of *V*, for *F*, *B*, *P* and *G* because they are probabilities, and for *DF* because it is a standard discount factor.

Details about each of the variables is provided in the PAF Instruction Manual. Below is a brief comment about each of them.

Asset value (V)

V is estimated in question 1.2(b) of the PAF. It is a score that represents the value of this asset, assuming that the asset is in good condition. The scoring range is calibrated such that a score of 100 corresponds to an asset of very high national significance (such as the Gippsland Lakes). Each point of the score represents a value of $20 million.

Impact of works (W)

W represents the proportional increase in future asset value that would result if the project was fully implemented (i.e. assuming that it is fully adopted) compare to if it wasn't. It is estimated in question 2.6(b) of the PAF. *W* is measured as a proportion of the total value of the asset (in good condition). This is done to allow easy comparability across projects.

Technical feasibility (F)

F is a proportion which represents the probability that the benefits generated would be at least as large as specified in *W*. In other words, it is the probability that benefits will not be significantly less than *W*. It is estimated in question 2.7(b) of the PAF

Private adoption of works and actions (A)

A is a proportion representing the probability that the on-ground works and actions specified in the project will actually be adopted, assuming that the project is fully funded and the project's delivery mechanisms are implemented. It is estimated in question 3.3(b) of the PAF.

Preventing adoption of adverse practices (B)

B is a proportion representing the probability that the project will not fail due to adoption of adverse works or actions, despite efforts by the project to prevent that adoption from occurring. It is estimated in question 3.4(b) of the PAF.

Socio-political risks (P)

P represents the probability that other socio-political factors will **not** derail the project. This includes the risk of non-cooperation by other organisations and the impacts of social, administrative or political constraints. The latter can include resistance to the project at the political level, bureaucratic approvals that would be needed, or opposition by local government. *P* is the probability that the project will not be prevented from reaching its goal due to one or more of these factors

Long-term funding risks (G)

G represents the probability that essential long-term funding will be available to continue to maintain the benefits generated by this project, or to complete the essential works commenced by this project. It is estimated in question 4.5(d) of the PAF.

Time lag to benefits (L)

L is the expected time lag in years until the desired bio-physical outcomes would be achieved. It represents the earliest time when a large proportion of the benefits will occur. It is estimated in question 2.5(a) of the PAF.

Discount factor ($DF_B(L)$)

Benefits that occur further into the future are a lower priority than similar benefits that occur rapidly. This is captured through the use of "discounting". The discount factor is calculated as follows:

$$DF_B(L) = 1/(1.05)^L \qquad (6)$$

This assumes that the real discount rate (net of inflation) is 0.05. There is some debate about the appropriate discount rate to use for environmental projects. A real rate of 0.05 is a commonly used rate that is a little lower than rates commonly used for projects with financial outcomes, but not as low as argued for by a minority of the protagonists.

Up-front costs (C)

C is the sum of direct costs that will be incurred within the immediate time frame of this project – say, three to five years. This is a short enough time frame to ignore discounting (recognising that this simplification introduces a very slight error). *C* is recorded in question 4.4(b) of the PAF.

Ongoing or maintenance costs (PV(M))

Some costs may be incurred each year in the long term, such as monitoring and evaluation, or enforcement costs, or ongoing compensation payments. These costs, called *M*, are estimated in question 4.5(c) of the PAF.

To make them comparable to the up-front costs, we need to express them as a present value (*PV*). Calculate the PV as follows:

$$PV(M) = 10.7 \times M \qquad (7)$$

This assumes that the discount rate is 0.05 and the time frame for paying these costs is 20 years, commencing in year 4.

Compliance costs (PV(E))

These costs are only relevant if the project involves enforcement of regulations, meaning that people are required to comply with the project even if they don't wish to. The compliance costs represent the total annual net costs to private citizens from compliance. They do not include the costs to the project or other agency from enforcing compliance, as these should be included in the project budget in Q4.5.

A useful way to think about compliance costs is that they are the amount you would need to pay to citizens to make them indifferent between complying and not complying. This would account for any benefits (including compensation) that they receive as a result of complying.

If the private citizens are compensated for their compliance, then the compensation costs would need to be included in the project budget (Q4.5(b)) and cost provided for 4.5(d) would be reduced by the amount of compensation provided. Thus, the compliance cost should be the uncompensated compliance cost.

E is the aggregate compliance cost, in $million, across all citizens who do comply. As with project maintenance costs, these are assumed to occur for 20 years from the end of the initial project, and to have a real discount rate of 0.05.

$$PV(E) = 10.7 \times E \qquad (8)$$

Calculating the Benefit: Cost Ratio

We can now calculate the Benefit: Cost Ratio using equation (1). This provides an index that is comparable across projects, and provides an indication of the projects that should be higher in priority for public investment. The higher the value of the BCR, the higher the priority of the project (other things being equal).

For example, suppose the values for a project to enhance water quality in the Masterton Wetlands are as follows:

$V = 15$

$W = 0.25$

$F = 0.88$

$A = 0.7$

$B = 1.0$

$P = 0.98$

$G = 0.8$

$L = 20$; $DF_B(L) = 1/(1.05)^{20} = 0.38$

$C = 2.5$ (million $)

$E = 0.2$ (million $ per year); $PV(E) = 2.14$

$M = 0.25$ (million $ per year); $PV(M) = 2.675$

Now, combining those values into the *BCR*

$$BCR = \frac{V \times W \times A \times F \times B \times P \times G \times DF \times 20}{C + PV(M + E) \times G} \qquad (5)$$

gives *BCR* = 2.1. This value is compared with *BCR* values for other projects. The higher the value of the *BCR*, the higher the priority of the project. It is recognised that decisions would not be based solely on benefits and costs, but it should be a key input to decision making.

Comparing *BCR* across several projects to select a set for support, involves ranking the projects according to *BCR*, like this:

Project	**Benefit: Cost Ratio**	**Budget**
4	10.0	$3m
2	8.1	$13m
5	7.2	$1m
1	4.0	$6
6	1.1	$17m
3	0.8	$28m

If the available budget is, say, $17m then the analysis indicates that the greatest environmental outcomes from this investment would come from supporting projects 4, 2 and 5.

The *BCR* provides a score that is comparable across projects, and indicates which of the projects should be higher in priority for public investment. The higher the value of the index, the higher the priority of the project.

The *BCR* value required for a project to break even is 1.0. The 20 factor at the end of equation (1) is included to provide the intuitive result that the threshold value for the BCR is 1 (given that one point corresponds to a value of $20 million).

(To demonstrate, if the value for a particular asset X = $1 million, $W = 1$, $F = 1$; $A = 1$; $B = 1$; $P = 1$; $G = 1$; $L = 0$, so that $DF_B(L) = 1$, C = $1 million, E = 0 and $M = 0$, then the benefit: cost ratio for that project would equal 1. If the $V = 1$ corresponds to $20 million, then V for asset X = 1/20 = 0.05, and with this V, the $BCR = 1$. Thus if V is calibrated so that $V = 1$ corresponds to $20 million, then the break-even *BCR* value is 1.0.)

FAQs

601. The potential exists for investment decisions to be made by ranking on the BCR score alone. Isn't that a problem?

Any tool or system can be abused. Preventing this relies on the institutional arrangements and the individuals involved in decision making. We emphasise that the BCR is just an input to decision making. You would certainly want it to have a strong influence, but not to dominate other important considerations. To encourage decision makers to use the BCR in a balanced way, it is provided as one part of a Project Assessment Report. Also included in that report is information about time lags, risks, spin-offs, information quality and key knowledge gaps.

We note that if other factors influence decision makers to prioritise a project with a lower BCR, it is valuable to be able to see what is being given up. Thus, the use of the BCR improves accountability and transparency.

602. Why are the variables in the benefits part of the index multiplied rather than weighted and added?

The BCR has been carefully designed to be logical and conceptually sound. In summary form, it is calculated as follows:

$$BCR = \frac{V \times W \times A \times F \times B \times P \times G \times DF \times 20}{C + PV(M + E) \times G} \qquad (5)$$

In summary, starting with V as the asset value, W is multiplied because of the way it is defined as the proportional increase in value (so that overall benefits are proportional to W); A is multiplied because it is defined as a proportion of the required adoption and it is assumed that benefits are proportional to W; B, P and G are multiplied because they are probabilities; and $DF_B(L)$ is multiplied because it is a proportional discount factor.

This BCR formula avoids a serious problem that arises if variables are weighted and added up – a common approach in Multi-Criteria Analysis and in many *ad hoc* scoring systems. The big problem with additive systems is that a low score in one critical variable can be compensated for by high scores in other variables.

For example, if a project is not technically feasible, there is no way it should be supported, but using an additive system it may be. Indeed, a project that would achieve no outcomes whatsoever could be scored relatively highly within an additive system, even if the variables are scored accurately. This cannot happen in the BCR – if the impact of works (*W*) is zero, then the score for the whole equation is zero.

In general, the problem with additive systems is that, they often do not accurately reflect the benefits of the project, even if the numbers provided are completely accurate. Indeed, in principle, they cannot be consistently accurate. The example above with zero impact of works provides one illustration of this. As another example, suppose there are two projects that are identical except that in one case, the works make twice as much positive difference to asset condition as in the other. Logically, the benefits index for the first one should be twice as high as for the second. This would be accurately reflected in the BCR, because the value for *W* would be twice as high, and therefore the BCR would be twice as big. However, in an additive system, doubling the value of any variable cannot double the value of the index – the impact will always be less than the proportional change in the variable.

The following numerical example illustrates what can go wrong with a weighted additive system. Suppose the following values are assigned to the variables for four assets/projects.

Asset/ project	**Value (V)** 1-100	**Impact of works (W)** 0-1	**Technical feasibility (F)** 0-1	**Adoption (A)** 0-1	**Adverse adoption (B)** 0-1	**Socio-political risks (P)** 0-1	**Long-term funding (G)** 0-1	**Lag (L)** 0-100 years	**Cost** $ million
Wilson Wetlands	15	0.25	0.88	0.7	1	0.98	0.8	20	5
Rogers River	80	0.01	0.83	0.5	1	0.85	0.9	15	3
Riley Reserve	5	0.5	0.93	0.6	1	0.98	0.5	10	2
Patterson Park	5	0.25	0.93	0.6	1	0.98	0.5	10	2

For the purposes of illustration, suppose the following weights are used in a weighted additive scoring system.

V	**W**	**F**	**A**	**B**	**P**	**G**	**L**	**Cost**
0.2	15	10	15	10	5	10	-0.5	-5

These weights have been chosen to reflect the sorts of weights that decision makers might actually choose. They are not crafted to generate the anomalies pointed out below.

The table below shows the results for the BCR and for the weighted additive scoring system using the above weights.

Project	**Benefit: Cost Ratio**		**Weighted additive scoring**	
	Score	Rank	Score	Rank
Wilson Wetlands	2.8	3	14	4
Rogers River	0.8	4	33	1
Riley Reserve	12.0	1	32	2
Patterson Park	6.0	2	28	3

Note that it does not matter that the BCR scores are lower than the weighted additive scores. This just reflects the different scoring systems. It is only meaningful to compare scores within a column.

Given the way that these variables have been defined, the Benefit: Cost Ratio accurately reflects the relative cost-effectiveness of the different projects – the environmental benefits per dollar spent. If you wanted to maximise environmental benefits you would prioritise the funding of these projects in the rank order of their BCRs.

In the example above, the ranking of projects using the weighted additive scoring system is very different. In particular, the project that provides by far the worst value for money (Rogers River) is given the highest score! This is mainly because the project has a very low impact on asset condition, but the additive scoring system does not adequately reflect this. In addition, although the Riley Reserve project is actually twice as good as the Patterson Park project, using the weighted additive scoring system, their scores are little different.

The errors in ranking caused by the weighted additive approach are not always serious, but they can be. It depends on the particular weights and scores used in each particular case. Fortunately it is easy to avoid the problems by using the BCR or something similar.

603. How does the BCR assist with comparing assets/projects of different scales, durations and types?

Comparing assets/projects of different scales, durations and types has always been a challenge for managers of natural assets. Because of the way it is designed, the BCR assists greatly with this problem.

In principle, the ideal decision method is one that results in the most valuable outcomes overall, given the available budget. The BCR is theoretically consistent with this ideal.

In the BCR, benefits are measured in a way that allows comparison across different types of assets. A key factor in allowing this is standardisation of asset scores (V). Then the other variables in the benefits index are all expressed as proportions or probabilities, so that the unit of measure for the benefits index (the numerator of the BCR) is essentially the same as for V. Because benefits are measured using the same scale for every asset type, it is valid to compare benefits for projects of different types of assets (e.g. rivers vs land vs native vegetation). Costs are also measured in the same way for each asset type (dollars!), and so they too can be validly compared.

In the BCR, the benefits index is divided by total project costs to provide an estimate of the expected level of benefits per dollar spent. This allows us to compare the merits of projects of different scales. The decision rule is to choose the projects with the highest BCRs, down to the point where the budget is exhausted (exactly the same as with Benefit: Cost Analysis). At least that is the starting point, to be modified following discussion of other relevant considerations (see FAQ 601).

We assume that costs are costs, irrespective of project duration. Imagine two projects with exactly the same benefits (level and timing), and exactly the same overall costs, except that one project spreads the costs over four years instead of two. (We would allow for discounting when comparing the costs of the two projects.) In principle, any assessment tool used to compare the two projects should give them exactly the same overall score, irrespective of their different durations. The BCR is consistent with this requirement, because it uses total costs (discounted if necessary) irrespective of project duration.

In summary, the standardisation of *V* and the use of multiplicative proportions allow comparison of projects for different types of natural assets, and dividing by costs allows the comparison of projects of different sizes and durations.

604. I'm looking at two projects that are mostly very similar, except that one has higher costs. INFFER gives them quite different values for the Benefit: Cost Ratio (BCR). Is that right? Doesn't this bias investment against the project with the higher costs?

Suppose you were looking at buying either a Toyota Corolla or a Honda Civic, and you liked them both equally, but the Toyota was much cheaper. Which would you buy? To buy the more-expensive Honda, you'd have to think it was superior to the Toyota by enough to justify the extra expense. That is exactly what the BCR is capturing for environmental projects.

The BCR represents the benefits of a project divided by the costs of the project. If you have a lot of projects to choose from, and a fixed total budget to invest, the way that an investor can maximize their overall benefits is to choose the set of projects with the highest benefit: cost ratios.

For example, suppose there were 10 projects, each with gross benefits of $10 million, and each with a different level of costs: $1, $2, $3, $4, $5, $6, $7, $8, $9 and $10 million. If you have a budget of $10 million, the best strategy is to choose the first four projects, which have benefit:cost ratios of 10, 5, 3.3 and 2.5. Your total gross benefits would be $40m and your net benefit would be $30m (= $40m – $10m). If you chose the fifth project (benefit:cost ratio = 2), you would have to drop, say the fourth and the first projects to pay for it. The gross benefit would fall to $30m, and total costs would stay at $10m, so your net benefit would fall to $20m (= $30m – $10m). Clearly, projects with the highest BCRs are the priorities.

Note that if one project is just a scaled up version of another one, and the benefits and costs are scaled up by the same proportions, then the BCR will be identical for the two projects.

605. How does the size of an asset affect its Benefit: Cost Ratio score?

If asset A is larger in scale than asset B, this influences the INFFER assessment in several ways, and these influences flow through to the Benefit: Cost Ratio. For the purposes of illustration, assume that, apart from their sizes, the two assets are basically identical.

- Asset A would have a higher score for asset significance (Q1.2(b)).
- Asset A would require more extensive resources to be maintained at the same quality (e.g. more extensive works and actions specified in Q2.2).
- If the project for asset A provided the required extra resources, the score for technical effectiveness would be similar for both projects. If the extra resources were not provided, asset A would have a reduced score for technical effectiveness.
- If asset A requires more extensive changes in land management than asset B, then asset A may have a lower score for the attractiveness of changed practices.

All of these factors would feed into the calculation of the Benefit: Cost Ratio. The BCR for asset A may be higher or lower than for asset B, but on balance is more likely to be lower.

See also FAQs 64, 65, 70, 106.