Limestone analytics

Unified Cost-Benefit Analysis (UCBA) Guidelines

Live Version

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Acknowledgements

The development of Unified Cost-Benefit Analysis, or UCBA, started in 2016 at **Limestone Analytics** (Limestone) with the objective of making evidence and economic analysis more accessible to decision-makers. UCBA has gone through many iterations over the years. It has benefited from the feedback and comments of many professional practitioners, including Jordan Nanowski, Simon Rivard, Jay MacKinnon , Zuzanna Kurzawa , Ardyn Nordstrom , Frederic Tremblay , Jenny Watts, Christopher Cotton , Kristen Schubert , Nathan Martinez , and Kemal Bagzibagli. Limestone has used UCBA to develop and specify more than 50 cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) models for the United States Agency for International Development (USAID), Millennium Challenge Corporation (MCC), Conservation International, Nutrition International, Copenhagen Consensus Center, World Health Organization (WHO), Sight and Life, World Vision, Chemonics, and other clients.

1. Introduction

1.1 Background & Problem Statement

Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA)[1] are tools to assess the relative merits of policies and interventions. There is general agreement within the public investment community that it is good practice to apply CBA to improve the quality of public sector investments (World Bank, 2023). For this reason, many governments, including those of Australia, Canada, France, New Zealand, and the United States, as well as the European Union, require or recommend the conduct of CBA for public investments or as part of their regulatory analysis (Dobes et al., 2016; European Commission, 2015; Kashi et al., 2022; OMB, 2023; Quinet et al., 2013; Treasury Board of Canada Secretariat, 2018). As of 2021, all OECD members required regulatory impact analysis on at least some laws to assess the likely benefits and costs of particular regulatory approaches and to inform decision-making (OECD, 2021).

The conduct of CBA faces a number of practical challenges distinct from the many outstanding theoretical challenges. Within the public investment community, there is an acknowledgment that the application of CBA may not be comprehensive or systematic in all cases (World Bank, 2023). The construction of CBAs is often idiosyncratic, varying by analyst (or analyst team). The documentation of CBA models' structure, assumptions, and inputs is similarly inconsistent across analysts and organizations (Dobes et al., 2016).[2] [3] [4]

These inconsistencies result in three specific challenges for the practice of CBA:

1. **Limited Auditability, Accuracy, and Rigor:** For most CBA models, experts must review a sizeable spreadsheet or programming codes line by line or rebuild the model to understand how it works. Quality control is, therefore, time-intensive and expensive. As a result, a full audit of CBA models is uncommon, and most CBA models are only loosely audited. Without sufficient quality control and peer review, the accuracy and rigor of CBA models may be questionable.

[1] References to CBA within this document extend to CEA, but are abbreviated for efficiency's sake.

[2] "Finding relevant assumptions, data and results in idiosyncratic CBA studies is difficult because there is no pattern or location to assist readers to find information" (Dobes et al., 2016: 141). This is particularly the case for complex, detailed, and lengthy studies. "Reading such reports, even if they are technically rigorous, is time-consuming, even for experienced users of CBA analyses, because it is necessary to identify the key components and to check for internal consistency" (Dobes et al., 2016: 68).

[3] Most organizations require some form of a report to accompany a CBA model. The publication of CBAs within academic journals similarly requires formal specification of methods using formulas and the provision of citations for all parameter values. However, these reports are not standardized and often incomplete, requiring an audit of a CBA model to understand it in full. Furthermore, reporting imposes costs beyond the CBA model construction both for the initial report and updates to reflect subsequent changes in the CBA model.

[4] Practitioners of cost analysis raise similar concerns, noting that inconsistent and non-transparent methods, assumptions, and reporting limit the use and assessment of cost data (Vassall et al., 2017).

2. **Reliability at a Cost:** Because quality control is expensive, building models quickly and subjecting them to rigorous audits is not typically a cost-effective approach to producing accurate and rigorous analysis. Organizations that set high-quality standards for CBA often rely on a few experts with many years of experience to generate CBAs, but at a significant cost.

3. **Limited Reuse:** The limited auditability of CBA models limits opportunities to reuse or draw substantially from existing CBAs.

Taken together, these challenges tend to drive up the time and cost of conducting CBAs and undermine their quality, limiting the use of CBA in designing and evaluating policies and interventions.

A repeated response to these challenges has been to develop software programs and tools that can standardize the CBA model, allowing users to apply a single model with a given methodology and ensure that results are internally consistent. For example, the World Bank and several partner agencies developed the Highway Development and Management (HDM) Model to inform road administrators in the analysis, planning, management, and appraisal of investment decisions in the transport sector (World Bank, 2022). HDM is widely used but limited in its application as it is specifically for a subset of transport infrastructure. A similarly narrow CBA model is the United Nations Sustainable Development Group's (SDG) Common Premises Cost Benefit Analysis Tool. This tool consists of ten linked and formatted spreadsheets (United Nations, 2016a) for UN agencies to assess where to locate their physical premises (offices) in light of different cost expectations (United Nations, 2016b). More recently, the World Bank launched a digital, online application to facilitate the use of CBA within public sector decision-making. The purported advantages of this eCBA platform include that it is structured and user-friendly and delivers standardized evaluations and transparent analysis. The tool also facilitates "coherent information exchange" within participating organizations. Its intended application is for most public investment projects, except the most complicated investments, generating a reference database of assessed projects over time. The eCBA tool allows users to input the costs, benefits, and their annual values within the model but does not require an explanation of how those values have been determined (World Bank, 2023).

If, as "most academic texts implicitly recognise … uniformity in approach [to CBA] is neither desirable nor practicable" (Dobes et al., 2016: 67), then a single CBA model that applies to all investments does not and cannot exist. Instead, calls have been issued not for standardized tools but rather for a paradigm to organize and present work in ways that can support the review, communication, elaboration, or replication of a CBA. For example, a recent report suggests that USAID CBA reports and documentation should include a description of the intervention, the benefits, costs, and stakeholders involved, the methods used to quantify benefits and costs, and parameter values and their sources in addition to the results of the analysis (Kashi et al., 2022). The European Commission (2015) calls for a CBA dossier or report to detail the methods and tools used, the working hypotheses underpinning the analysis, and forecasts and sources of future values, which is therefore:

- Self-contained, briefly recalling and illustrating results of previous studies;
- Transparent, making easily available a complete set of data and sources of evidence;
- Verifiable, clearly presenting assumptions and methods used to calculate forecast values so that the analysis can be replicated by a reviewer; and
- Credible, in that it is based on well-documented and internationally accepted theoretical approaches and practices.

Dobes et al. (2016) go a step further in calling for the adoption of a harmonized framework marked by consistency in the order of presentation of the component steps, which would improve transparency for readers seeking specific information from a CBA study. Based on a review of academic texts, Dobes et al. (2016) suggest the following approach:

1. Specify the objective of the analysis.
2. Define 'standing' or perspective and scope.
3. Establish the base case, reference point, or counterfactual.
4. Predict the effects of the policy or project over its life cycle.
5. Estimate the economic value of the costs and benefits.
6. Adjust costs and benefits for risk.
7. Calculate the net present value of the costs and benefits.
8. Conduct sensitivity analysis.
9. Determine distributional consequences and distributional weighting of costs and benefits.
10. Arrive at a conclusion or recommendations for the CBA.[5]

The approach proposed by Dobes et al. (2016) provides the operational steps of a comprehensive paradigm. It lists the common elements and information that need documentation during the development of CBA models and the relevant analysis. However, there remain gaps in operationalizing this paradigm in a way that is logically, structurally, and visually consistent.

1.2 UCBA: Uses & Principles

This paper introduces a set of conventions and specification tools for CBA, referred to as Unified CBA or UCBA.[6] Together, these conventions and tools help standardize how CBA models are specified. UCBA is a model specification language, not a methodology for conducting CBA. The objective of UCBA is to allow practitioners to document CBA models

[5] Robinson et al. (2019) propose a very similar "checklist" to ensure that a CBA contains all essential components necessary to align with their guidelines for CBA.
[6] The term UCBA is used as a matter of convenience. UCBA can equally extend to CEA without any significant adjustment to address outputs in non-monetary terms such as the number of years of education gained, disability-adjusted life years saved, etc.

using a standardized notation, thereby reducing the cost of auditing and quality control. A common documentation standard is thus an important step in transitioning CBA from an academic exercise to a professional practice and in institutionalizing and expanding the use of CBA to inform decision-making.

The relationship between UCBA and CBA is similar to that of blueprints and architecture or standard financial statements and accounting. It is difficult to imagine how a construction project can happen without blueprints or financial accounting can be performed without income statements and balance sheets. These specification instruments were developed to facilitate these professional practices. UCBA is intended to play a similar role by serving as a specification language for the practice of CBA.

The potential contribution of UCBA to the professional practice of CBA is significant, offering conventions and tools that are adaptable to assess a diversity of policies and interventions. As a model specification language, UCBA does not restrict or dictate the underlying economic theory for quantifying and valuing the costs and benefits, nor prescribe the choice of software program to perform the calculations.[7] Moreover, knowledge of UCBA does not qualify the reader of this concept paper as a CBA expert.[8] Nevertheless, proper specification of CBA models enhances the ability of the analysts to interact efficiently with peer reviewers, clients, and subject area experts regarding the model's assumptions, logic, and results. Therefore, using a specification language such as UCBA reduces the time and effort needed to create and maintain reliable CBA models.

A specification language should adhere to two characteristics to be fit for purpose. First, it should be **efficient**, meaning that it should make it easier for an auditor to review and understand a CBA model without adding excessive burden on those who develop these models. Creators of CBA models require an iterative process to refine and improve these models as they calculate each cost and benefit. Auditors are interested in seeing the big picture and then selectively dive in to check the calculation methodology, robustness, and accuracy for each cost and benefit. These requirements and expectations of CBA modellers and auditors are incompatible without an efficient specification language: Many CBA models include chains of interlinked calculations, making it impossible to audit the methodology and calculations without reviewing or reconstructing the entire model. Second, a specification language must also be **comprehensive**. With the specification in hand, any modeller should be able to replicate the CBA and arrive at the same results. Comprehensiveness means an explanation that goes beyond the core of the methodology

[7] A model that is properly specified in UCBA can be implemented in any software platform such as Microsoft Excel, Matlab, Google Sheets, etc.

[8] Qualification as a CBA expert requires knowledge of welfare economics and CBA. See Adler and Fleurbaey (2016) for an overview of CBA and other approaches used for the analysis of public policies and development projects. Depending on the sector, conducting a CBA might require additional knowledge of project finance, public finance, engineering, or other sectoral expertise.

and covers every detail, from the relevant timing for each cost or benefit to the citation for every parameter value to the way each decision criterion is calculated.

This document, therefore, proposes UCBA as an efficient and comprehensive specification language suitable to address challenges currently facing CBA practitioners in two ways:

1. Change the order of the process and promote a new modelling paradigm in which the CBA expert starts by specifying the model (like an architect), leaving the construction of the model as a future step once the methods are fully developed.

2. Eliminate the need to audit a CBA model line by line in order to understand the underlying methodology and assumptions.

1.3 Structure of Document

This document has four main sections. Following this introduction, Section 2 briefly presents **key concepts underpinning UCBA**. Section 3 focuses on the **specification instruments and the recommended operational steps** for using UCBA to develop and specify a CBA or CEA model. Section 4 offers discussion and conclusions. Appendices contain supplemental material, including the **documentation conventions** used at Limestone for operationalizing UCBA to allow for teamwork and consistent reporting and practical considerations, as well as a **checklist for practitioners** to test the degree to which they currently comply with UCBA principles.

2. Common Elements & Principles Underlying UCBA

For UCBA to be comprehensive and efficient, it must account for all common elements of every CBA model in specifying the functionality and utility of the model. Furthermore, UCBA must follow a set of common principles as ground rules that drive consistency while maintaining flexibility in application.

2.1 Common Elements of CBA Models

Every CBA model comprises four elements:

1. **Logic**: The costs and benefits of the decision (policy or investment).
2. **Methodology**: The calculations for estimating the costs and the benefits.
3. **Inputs**: The inputs used for the calculations (parameters and their values).
4. **Outputs**: The decision criteria that eventually form the outputs of the analysis (e.g., net present value (NPV), internal rate of return (IRR)).

These common elements are always included in all CBA models. However, they are not represented or communicated in the same way from one CBA to another.

An important but sometimes neglected aspect of a CBA's logic is **perspectives**.[9] In most CBAs, there is only one perspective, typically that of the country as a whole or a global perspective.[10] Integrated analysis refers to the practice of constructing CBA models that include multiple perspectives, such as financial (e.g., investors), country, global, and subgroups. In integrated CBAs, the calculation of costs, benefits, and investment criteria considers alternative perspectives. Here, each cost or benefit can have a different value based on the perspective, which can be defined according to subgroup (e.g., beneficiaries, government, investors) or geography (e.g., economic region vs. global). Transfers are impacts that are a cost to one perspective and a benefit to another, resulting in a net zero effect when considering both perspectives.[11]

2.2 Functionality and Utility of CBA Models

CBA models are typically constructed to use inputs and assumptions to forecast a set of time series. These time series data can represent quantities of inputs and outputs or the value of costs, benefits, and transfers. The UCBA paradigm primarily focuses on specifying

[9] Indeed, "Many CBA studies fail to define explicitly the perspective from which costs and benefits are to be included or excluded" (Dobes et al., 2016: 73).
[10] Within CBA, a national perspective often serves as the default (Dobes et al., 2016, citing Boardman et al., 2011).
[11] For instance, a tax can be a benefit for the tax authority and a cost to a business. However, the tax is not an economic cost or benefit from the country's perspective.

the conversion of inputs to time series, such as quantities of services and products consumed and produced, prices, benefits, costs, and transfers. This conversion is **the core functionality of the CBA model**.

However, CBA needs to summarize the analysis in the form of decision criteria before it can be useful. The time series discussed above provide the data from which the model can calculate the decision criteria. The most commonly used decision criteria are net present value (NPV) and internal rate of return (IRR). However, UCBA can also specify other decision criteria such as benefit-cost ratio, cost-effectiveness ratio, number of people reached, or measures of risk and uncertainty (such as confidence intervals or the chance of failure). Converting time series into decision criteria is **the utility of the CBA model**.

2.3 UCBA Principles

2.3.1 Benefits and costs (impacts) are the primary anchors of UCBA

CBA considers a set of impacts (costs, benefits, and transfers) attributable to the decision, policy, or investment being analyzed. These impacts are the main anchors of UCBA. UCBA can be structurally different from a conventional incremental analysis, but the two are not fundamentally inconsistent. For instance, the conventional incremental analysis of an agricultural intervention can define benefits and costs as the benefits and costs to those impacted (i.e., farmers). UCBA defines costs and benefits as the incremental change borne by those impacted (e.g., increase in farm output, reduction in losses, or increase in cost). This distinction is only an alternative way to present the same information and is not a methodological difference. UCBA can still produce and report benefits and costs to the beneficiaries or impacted parties with and without the decision (project or policy).[12] However, the main structure builds on the costs and benefits of the decision being analyzed by the study.

Benefits and Costs in Conventional Analysis	With	Without
Benefit: Farm revenue	$15	$11
Cost: Farm cost	$10	$8
Net Impact	$5	$3

Benefits and Costs in UCBA	Incremental Impact
Benefit: Increase in farm revenue	$4
Cost: Increase in farm cost	$2
Net Impact	$2

Figure 2.1 Example of Incremental Analysis and UCBA Approach

[12] That is, the explicit calculation of with and without resource (cash) flows is fully compatible with UCBA.

2.3.2 Logical integrity is more important than consistency

Costs and benefits of the same decision, policy, or project can be defined and named in different ways. For example, a transport project can change the maintenance cost of a road. The analyst might record the "change in maintenance cost" as either a benefit or a cost in UCBA: If the maintenance cost of the road goes up as a consequence of the decision, then this impact can be either a negative benefit or a positive cost. UCBA does not prescribe whether the change in maintenance cost should be a benefit or a cost. What matters is that it should have the sign that maintains logical integrity (an increase in cost due to the decision must be captured as a negative benefit or positive cost in UCBA).[13]

2.3.3 Specification of each impact must be independent

For every cost or benefit, UCBA requires the specification of the calculation methodology along with the formulas and all required exogenous inputs. Impacts must be specified independently. Each impact must be specified using a narrative (text that explains the calculation method and critical assumptions and that includes key references for the choice of method) with the stipulation of the applicable timeframe,[14] a list of exogenous inputs, and formulas to convert the inputs into time series for the impacts.

It is common for the same production function to be relevant to multiple impacts. For instance, a farm's yield is a determinant of the production value (benefit) as well as the post-harvest costs. To ensure the independence of each impact, no impact can use the results of another impact's calculations within its inputs. For the calculation of each benefit and cost, all exogenous inputs must be listed. The naming of inputs must be unique across the model.[15] Independent specification allows for more efficient peer review and model maintenance. Following this approach, a peer reviewer can review the calculation of one benefit or cost without reviewing the entire specification, and the analysts can update calculations without worrying about how intermediary calculations for one benefit or cost might affect others.

2.3.4 Independent specification should not undermine integrity

Despite the independent specification of impacts, the analyst must avoid redundancies that can affect the model's integrity. For instance, if benefits per impacted beneficiary depend on their province but the costs only depend on the total beneficiary count, then both benefits and costs should use the number of beneficiaries by province as an exogenous

[13] Other (sectoral) sources may offer more prescriptive guidance for defining and classifying benefits and costs, as Robinson et al. (2019) with respect to the impacts of public health interventions.
[14] Most CBAs come with a timeframe, but not all impacts are relevant to the entire timeframe. For example, costs and benefits may only be relevant during the investment and operation phases, respectively. Calculation methods may change over time depending on the intervention phase. Where possible, analysts should simplify the process rather than adding too many time horizons.
[15] It is normal for an input to appear in the calculation of more than one benefit and cost. In such cases, the name must be consistent across all calculations.

input. In this case, the total beneficiary count should be a calculation (sum of beneficiary count by province across all provinces) in the calculation of all costs, and it would be a mistake to treat the total beneficiary count as an input.

2.3.5 Complexity should be at the minimum possible

To the greatest degree possible, complexity must be minimized. The most common approach to specifying a calculation is by using mathematical formulas. However, CBA practitioners frequently skip the mathematical specification and rely on spreadsheets with many interlinked cells spread across rows and columns as the only reference for the methodology. The majority of these cells include small or large formulas. Specifying the calculations in mathematical formulas requires condensing these scattered formulas into simpler ones. There are conventions that can help present CBA calculations in condensed forms. These include using dimensions and consistent formulas across time, which will be covered later in this article.

The use of annexes can also help minimize complexity. It is common for CBAs to use inputs estimated from primary or secondary data. For instance, the average income of participants can be estimated using primary data from a survey. Although relevant to the CBA, such calculations are not a part of the CBA methodology and so do not need to be specified in line with UCBA. CBA only uses the result of the calculation as an exogenous input. Therefore, such calculations can be specified in annexes rather than the main UCBA specification.

3. UCBA Specification Instruments

3.1 Overview of UCBA Instruments

Practitioners construct most CBA models like building blocks, starting with a key element - say, an important cost or benefit - and adding other calculations piece by piece to complete the structure. This approach follows an undetermined, evolving thought process, which is not structured or efficient. Models quickly become large and complicated. Tracing calculations (or errors therein) can become a challenge in itself, requiring a spreadsheet wizard to untangle the wiring before making an update.

UCBA simplifies this process by proposing an alternative approach to conceptualize and specify a CBA model before and while programming it into a functional form. This approach facilitates peer review of the methodology without the need to review a functioning model. The approach consists of the following steps:

1. Identify the main impacts (costs, benefits, and transfers) and perspectives;
2. Identify the decision criteria and critical assumptions[16];
3. Specify the methodology for calculating each impact, including identifying the exogenous parameters; and
4. Find parameter values, implement the model, and report the results.

UCBA uses four instruments to facilitate this process. These instruments comprehensively specify all the elements of a CBA model. A tabular structure is used for all UCBA instruments. The central instrument is a series of tables, each specifying the underlying methodology for estimating a benefit, a cost, or a transfer. Collectively, these tables are called "Quantities and Values" or Q&Vs. The remaining instruments describe the breadth (how many Q&Vs?) and the depth (how detailed should each calculation be?) of the model, how the costs and benefits come together to inform decisions, and how to populate the model. For example, the "Decision Criteria and Sensitivity" (DC&S) instrument defines the required depth for each calculation. **Table 3.1** lists the four UCBA instruments and the information that they carry.

[16] Per Kashi and Hyman (2023), critical assumptions are the design parameters and risk and uncertain variables.

Table 3.1. List of UCBA instruments and the information they carry

<table>
<tr><th>UCBA Instrument</th><th>Content</th></tr>
<tr><td>Benefits, Costs, & Perspectives (BC&P)</td><td>The list of impacts (benefits, costs, and transfers) and perspectives</td></tr>
<tr><td>Decision Criteria & Sensitivity (DC&S)</td><td>Including two parts:
1. Key decision criteria, including the visual elements, subgroup analysis, and measures of risk and uncertainty.
2. Critical assumptions, including their range for sensitivity analysis, possible combinations for scenario analysis, probability distribution for probabilistic analysis (when applicable), and the impacts that must be sensitive to the value of these assumptions (their related impacts).</td></tr>
<tr><td>Quantities & Values (Q&Vs)</td><td>For each impact, a Q&V instrument specifies:
● How to quantify?
● How to value?
● Which inputs to use?
● What to report?
Additional Q&Vs may include the calculation of time periods and annexes that contain any calculation kept outside the core CBA methodology.</td></tr>
<tr><td>Inputs</td><td>Exogenous parameters, including their names, values, units, and sources</td></tr>
</table>

These instruments are logically interconnected in the following ways:

- For every impact in the BC&P instrument, there is a Q&V.
- For every impact in the BC&P instrument, there is at least one related perspective.
- For every related perspective of an impact, there is a calculation in the corresponding Q&V.
- All impacts are represented in the DC&S instrument.
- The critical assumptions in the DC&S instrument appear as exogenous inputs in the Q&V of their related impacts.[17]
- Each critical assumption in the DC&S instrument has at least one related impact.
- If a timeframe identified in the Q&Vs needs an intermediate calculation, this calculation is specified in an additional Q&V.
- All unique inputs identified in the Q&Vs are listed within the inputs instrument.

[17] See the content of DC&S in Table 3.1 for the definition of "related impacts."

- Exogenous inputs are named consistently[18] and are independent across all Q&Vs.[19]

Two notes are important at this point. First, these instruments must collectively produce ALL the information necessary for someone without the knowledge of economic analysis to put a functioning model together. Second, the process is iterative, meaning that while the creation of these instruments comes with an order, they will all go through rounds of refinement during the implementation, parameterization, and analysis.

Figure 3.1 illustrates how the UCBA instruments are logically interconnected. Note the dotted line between the DC&S and the inputs instruments. This line signifies that some calculations might be considered too simple to require a Q&V, therefore, the inputs they require must find an alternative way to reach the inputs instrument. The best example is the baseline discount rate: While it is a critical assumption for the majority of CBAs, its use might be limited to the calculation of the net present value (NPV) as an investment criterion, which is a simple function in most spreadsheet programs and the practitioners might not specify a Q&V for it. In such an example, the discount rate will appear in the DC&S, but if there is no Q&V for the NPV function, then it goes directly to the inputs instrument.

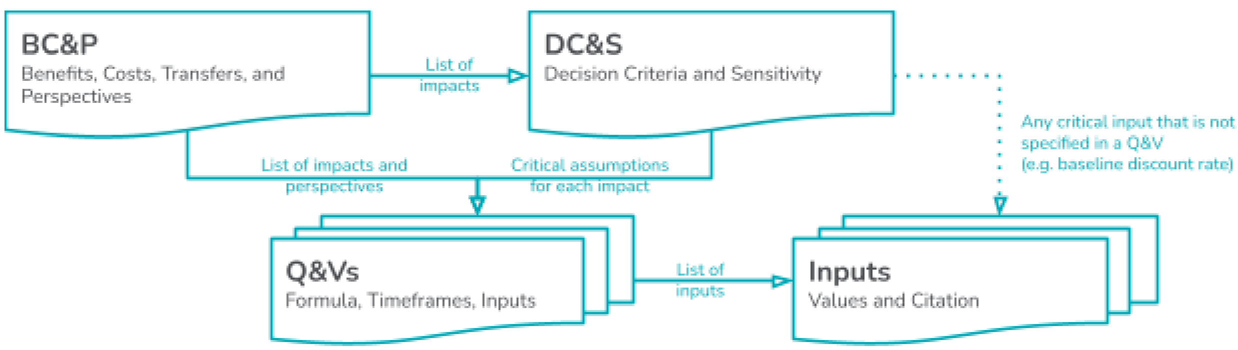

Figure 3.1. UCBA Instruments

All UCBA instruments can be documented by practitioners as tables. This document uses tables as the standard notation to illustrate the structure and elements of each instrument.

Below, we consider the four instruments in detail and use an example to illustrate their application. This example considers a campaign to increase awareness about the cost of electricity during peak hours. The campaign will promote rescheduling energy-intensive activities, such as operating a washing machine, away from peak consumption hours.[20]

[18] For instance, if price of an input is named p in one Q&V, it should be represented with the same name should it appear in another Q&V.
[19] For instance, x, y, and z cannot be three exogenuous inputs if z is equal to the sum of x and y.
[20] A further, consolidated example of UCBA instruments is provided in Annex 3.

3.2 Benefits, Costs, & Perspectives (BC&P) Instrument

One of the simplest and yet most critical instruments of UCBA is a list of all impacts (benefits, costs, and transfers) resulting from the decision, policy, or intervention under consideration (**Table 3.2**). This instrument helps communicate the breadth of the CBA and allows reviewers, auditors, or decision-makers to transparently identify the impacts and any omissions from the analysis (Dobes et al., 2016). The benefits and costs included in this instrument can be financial or non-financial (economic) in nature.

Table 3.2. Structure of a BC&P instrument for a non-integrated CBA (single perspective)

Benefit 1 - name
Benefit 2 - name
...
Cost 1 - name
Cost 2 - name
...

To illustrate, consider the benefits and cost of the electricity time of use campaign as illustrated in **Table 3.3**. In this example, similar to many other CBAs, the perspective assumed for defining the benefits and costs is the economy or the country. Notably, as we learn more about the impact of policies and projects beyond the borders of a given country (such as GHG emissions), it has become more important to clarify whether a CBA is taking a global or a country perspective.

Table 3.3. BC&P of the electricity time of use campaign (non-integrated, economy's point of view)

Benefit 1 - Reduced cost of electricity generation
Benefit 2 - Reduced GHG emissions
Cost 1 - Campaign cost

This instrument can expand for an integrated analysis. An integrated BC&P should list the benefits, costs, and transfers in the first column and add subsequent columns for the various perspectives, starting with financial stakeholders, followed by the various external stakeholders.[21] In this case, a simple check mark signifies if a benefit, cost, or transfer applies to and so requires calculation for the corresponding perspective. Practitioners must ensure that a transfer is always marked with at least two check marks, of which at least one is negative (-) and at least one is positive (+). This notation helps to ensure that transfers are correctly accounted for and in balance, as at least one perspective will pay for the transfer (-) and at least one perspective will receive the transfer (+). **Tables 3.4** and **3.5**

[21] A single impact can have a financial and an external impact. For example, a water tariff policy that reduces the price of water for the consumers has an external impact for consumers (cost saving) that is different than the financial impact on the water utility (change in sales revenue).

provide a framework and an example of a BC&P instrument for integrated analysis.[22] Annex 1 provides more detailed guidance on constructing BC&P instruments for integrated analysis.

Table 3.4. Structure of a BC&P instrument for an integrated CBA

	Subgroup 1	Subgroup 2	Other (e.g., economy)
Benefit 1 - name	✓		✓
...		✓	✓
Cost 1 - name	✓	✓	✓
...			
Transfer 1 - name	✓-	✓+	0
...			

Table 3.5. BC&P of the electricity time of use campaign (integrated)

	Public Utility	Consumers	Country
B1 - Reduced cost of electricity generation	✓		✓
B2 - Reduced GHG emissions			✓
C1 - Campaign cost	✓		✓
T1 - Change in consumer electricity charges	✓-	✓+	0

Practical Considerations

1. **How to identify and organize benefits, costs, and transfers in the BC&P instrument?** Benefits, costs, and transfers (flows) can be identified with the notation of B, C, and T, respectively. Flows can be numbered for ease of reference, as in B1, B2, B3, C1, C2, T1, etc. It is suggested to organize flows by type within the BC&P instrument (benefits, then costs, then transfers). Within these, it is suggested to begin by listing the most to least conceptually important (which may or may not ultimately correspond with magnitude).

2. **What is the right level of disaggregation for the BC&P instrument?** The level of disaggregation for benefits, costs, and transfers must be chosen efficiently, balancing between insight provision and ease of communication. The UCBA paradigm recommends an efficient breakdown, such that the impacts instrument requires no more than 15 rows and can fit on a single page. For instance, if operating costs include utilities, stationary, and rent, they can show up each as a separate cost

[22] With respect to Table 3.5, please note that this is a simple example for illustrative purposes. The assumptions that helped simplify the example include the absence of a sales tax on electricity consumption, a carbon tax on electricity generation, or any form of subsidy on consumption or generation. These simplifying assumptions remove the need to include the government as an additional perspective or changes to tax payments or subsidies as additional transfers.

or as a single cost - the operating cost. The decision to keep them separate or aggregate will depend on whether the separation adds any value to the communication of the results. If the disaggregation does not add any value, including the aggregate items is the more efficient approach. Note that the iterative nature of UCBA allows for the introduction of disaggregation later in the process.

3. **Can the subgroups in the BC&P instrument overlap?** UCBA does not prescribe any particular relationship among the perspectives included in an integrated analysis. As a result, perspectives can (but are not required to) overlap with each other. For instance, the economy or country, as a perspective, can be equal to the sum of the other perspectives. However, this relationship is not always an aggregation from left to right. For instance, perspectives based on gender and income group may overlap such that summing them can result in double-counting. Ultimately, the perspectives included must align with the reporting requirements. Therefore, the perspectives captured in BC&P typically undergo revisions when working on the DC&S instrument.

4. **How should practitioners handle the BC&P instrument for final reporting purposes?** A value - such as the present value of the benefit, cost, or transfer - can replace each checkmark in the BC&P instrument for final reporting purposes. The value of the benefit, cost, or transfer may differ for each relevant perspective. Each row will have a corresponding Q&V table, and each checkmark will be a calculation in the corresponding Q&V table. At the reporting stage, the BC&P can also have a new row at the bottom that shows the net impact from each perspective. This new row will show the sum of the values in each respective column.

5. **How can practitioners ensure that transfers are balanced?** At the reporting stage, if practitioners replace the check marks in BC&P with values: For each transfer, practitioners should cross-check that the horizontal sum across perspectives equals zero (is balanced).

3.3 Decision Criteria & Sensitivity (DC&S) Instrument

The DC&S instrument serves an important role in clarifying the decision criteria reported by the CBA model and stipulating the critical assumptions that may determine the model's results.

The first component of the DC&S instrument lists the decision criteria that the CBA model is intended to generate. These typically include outputs such as the NPV, economic rate of return (ERR), IRR, or BCR. These outputs may be required at an aggregate level (policy or investment as a whole) or disaggregated at relevant sub-levels (e.g., by geography or perspective). Additional outputs may be specific to a given analysis or to deliver information in a way that can inform design decisions. An example would be a threshold value for a critical assumption (such as an uncertain variable) at which an investment would return a positive financial or social net return. Other examples include visual presentations of benefits and costs over time, charts depicting the sensitivity of key outputs to measures of risk and uncertainty, or relative size of benefits and costs (waterfall or pie charts).

Which of these elements should be included in reporting? The answer to this question changes from one CBA model to another. Consider the DC&S instrument as the dashboard of a car. It summarizes the various indicators and allows the driver to change some of the inputs. The elements of a car's dashboard can differ from a sports car to a truck and from a petrol car to an electric car. The objective is to provide the user with what is needed to operate, nothing more and nothing less. The temperature of the brake system might matter to a rally driver but not to a taxi driver, who might be more interested in knowing the distance travelled and controlling the radio.

The decision criteria to report can require additional calculations and inputs beyond those included in the Q&Vs for each cost, benefit, and transfer. For instance, the benefit-cost ratio investment criterion requires its own calculation. It is important to specify this calculation since there are alternative methods for calculating this ratio. In such cases, the practitioner can add more Q&Vs to specify the calculation and inputs for the investment criteria.

The sensitivity component of the DC&S instrument lists the critical assumptions, which are a subset of those inputs the practitioner expects to include in the Q&Vs. A critical assumption can be a **decision factor** (such as the scale and scope of a project) or a **vulnerability** (such as the future inflation rate). In both cases, for the model to accommodate these parameters, its sensitivity to the parameter through all impacts (benefits, costs, and transfers) must be understood and formulated. UCBA should motivate practitioners to think carefully about the relationship between a critical assumption and all impacts, avoiding the mistake of automatically formulating the sensitivity of a subset of impacts to the parameter. For instance, the number of beneficiaries who decide to participate in a program may not only affect the program's benefits but also change its costs.

The main objectives of the second component of the DC&S instrument are to 1) list the critical assumptions (design parameters and risk and uncertain variables), 2) summarize which benefits, costs, and transfers are expected to be sensitive to critical assumptions, 3) specify the ranges and probability distributions to consider for each of the critical assumptions,[23] and 4) acknowledge correlations among critical assumptions for probabilistic analysis. This part of the DC&S instrument has the exact same first column as the BC&P instrument (the same benefits, costs, and transfers). The rest of the columns are, however, reserved for critical assumptions. It is strongly recommended that the baseline

[23] Readers are referred to Kashi and Hyman (2023) for more detailed, practical guidance on the identification and classification of critical assumptions as well as the execution of sensitivity analysis.

discount rate always be one of the critical assumptions subject to sensitivity analysis. A check mark indicates that the calculation of the impact in the corresponding row must include the input in the corresponding column. The table's final rows should present the range of the parameters as considered within the sensitivity analysis, the distribution of the parameters for Monte Carlo analysis (if applicable), and the correlations among the risk variables (if applicable). Please note that one can only specify a correlation between two risk variables and that each correlation appears twice in the DC&S. **Table 3.6** illustrates the structure of a DC&S instrument.

Table 3.6. DC&S instrument

Decision criteria

- **List the criteria and visuals to report out of the analysis (examples: NPV, IRR, BCR, BCR by region, BCR by component, cash flow over time chart, composition of impacts cumulative bar chart, composition of impact by stakeholder chart, etc.)**
- **Sectoral analyses may require additional decision criteria, for example:**
  - **Health and Nutrition: cases of disease/condition averted, lives saved/cases of mortality averted, DALYs averted, cost per DALY averted**
  - **Education: educational gains per person, cost per equivalent year of schooling**
  - **Environment: GHG emissions averted**
  - **Livelihoods: incremental income per perspective**

Critical Assumptions	Critical assumption 1 (unit)	Critical assumption 2 (unit)	Critical assumption 3 (unit)	Critical assumption 4 (unit)	Baseline Discount Rate (%)
B1 - Benefit 1	✓				✓
B2 - Benefit 2	✓	✓			✓
C1 - Cost 1		✓	✓		✓
C2 - Cost 2			✓	✓	✓
T1 - Transfer 1	✓				✓
T2 - Transfer 2		✓	✓		✓
Range for sensitivity analysis	[XX] to [YY]	[XX] to [YY]	[XX] to [YY]	[XX] to [YY]	[XX] to [YY]
Distribution for Monte Carlo analysis	Type: normal Mean: S.D.:	Type: triangular Most likely: Min: Max:	Type: step [min] to [max]: [pr.]% [min] to [max]: [pr.]% [min] to [max]: [pr.]% [min] to [max]: [pr.]% [min] to [max]: [pr.]%	Type: step [value]: [pr]% [value]: [pr]% [value]: [pr]% [value]: [pr]%	N/A
Correlations for Monte Carlo analysis	Critical assumption 2: 0.##	Critical assumption 1: 0.##			N/A

In the example of the electricity time of use campaign, we have identified the effectiveness of the campaign, price of fossil fuel, social cost of carbon, and the baseline discount rate as the critical assumptions (**Table 3.7**). Please note that, in this example, the theory and evidence suggest a zero correlation among the three risk variables for this DC&S instrument, except for the effectiveness of the campaign and the price of fossil fuel. Since the fossil fuel price is reflected directly in monthly electricity bills, the campaign is anticipated to be more effective at higher fuel prices.

Table 3.7. DC&S instrument of electricity time of use campaign

Decision criteria

- The net present value (NPV) from the economy, consumers, and utility perspectives
- The internal rate of return (IRR) from the economy and utility perspectives
- Line charts highlighting the sensitivity of the NPVs to the effectiveness of the campaign and the social cost of GHG

Impacts	Effectiveness of the campaign (%)	Price of fossil fuel (2021 USD)	Social cost of GHG per tonne (2021 USD)	Baseline discount rate (%)
B1 - Reduced cost of electricity generation	✓	✓		✓
B2 - Reduced GHG emissions	✓		✓	✓
C1 - Campaign cost				✓
T1 - Change in consumer electricity charges	✓	✓		✓
Range for sensitivity analysis	10% to 40%	50 to 150	0 to 200	3% to 10%
Distribution for Monte Carlo analysis	Type: normal Mean: 30% S.D.: 5%	Type: normal Mean: 100 S.D.: 60	Type: triangular Most likely: 100 Min: 0 Max: 200	N/A
Correlations for Monte Carlo analysis	Price of fossil fuel: 0.30	Effectiveness of the campaign: 0.30		N/A

While it may seem counterintuitive, UCBA prompts the practitioner to develop the DC&S instrument early within the process of preparing a CBA, even before the Q&Vs. The conceptualization of the DC&S instrument forces the practitioner to consider the design parameters and major expected sources of variability (risk and uncertainty) within the CBA and ensure their inclusion within the Q&Vs. The practitioner can thereby save time in the modeling process, avoiding the need to revise or retrofit calculations at a late stage of the analysis. The DC&S instrument supports the conceptualization of and methodology of the CBA, and UCBA therefore recommends that this instrument not be left to the final stages of the analysis.

Practical Considerations

6. **What is the difference between a risk variable and an uncertain variable?** Risk variables are subject to known variability, including the range of possible outcomes and the relative likelihood of their occurrence (e.g., market prices of traded goods). Uncertain variables are subject to unknown variability (e.g., the timing and magnitude of a natural disaster in a particular location) (Kashi & Hyman, 2023). Therefore, the difference between the two is whether their variability is known or unknown.[24]

7. **Should there be a limit to the number of critical assumptions in the DC&S?** Visually, fitting the DC&S instrument (typically structured as a table) to a single page will limit the number of parameters to four or five. The recommendation here is to keep the number of critical assumptions limited. While the analyst can include more, reporting sensitivity analysis for more than five parameters reduces the importance of each to the decision-making process, and some will only become a distraction.[25]

8. **What is the distinction between a sensitivity analysis and a scenario analysis?** To distinguish between sensitivity and scenario analysis, a rule of thumb is the number of critical assumptions (and so parameters) involved. If scenarios are only different values for a single assumption, then there is no need to do scenario analysis; it is simply a sensitivity analysis.

9. **When is the best time to complete the DC&S instrument within the model development process?** Using the DC&S instrument, the analyst can obtain feedback from the ultimate users of the analysis at the very early stages about the design decisions that CBA can help inform (design parameters) and main sources of risk and uncertainty. This way, if the ultimate users have questions about the impact of a specific assumption, such as cost or time overrun, the analyst will learn about it before the specification of the calculations. Later, during the analysis or if time brings new evidence and insights, the analyst might identify new critical parameters or decide that some parameters are no longer classified as "critical." Therefore, this instrument is expected to undergo multiple iterations throughout the model development and analysis. Important note: If a critical assumption is found to be of

[24] Stated alternatively, risk refers to "the distribution of the outcome in a group of instances [that] is known (either through calculation a priori, or from statistics of past experience). Risk is therefore often characterised as the calculable variation — positive or negative — around a point of central tendency of a probability distribution. By contrast, the probability of uncertain events is, by definition, not known or measurable" (Dobes et al., 2016: 94, citing Knight, 2009).

[25] Moreover, subjecting every parameter to sensitivity analysis may rapidly become intractable. For this reason, Dobes et al. (2016) recommend that analysts exclude from sensitivity analysis those variables in whose estimation the analyst has confidence, or which are obviously unlikely to influence NPV significantly.

less importance than initially thought, the analyst should document the justification for its removal for future reference.

10. **What if a critical assumption turns out to be an intermediary calculation?** Critical assumptions must be exogenous inputs. Analysts can identify a draft set of critical assumptions at an early stage of a CBA. Since the methodology for calculating each benefit or cost is unclear in the early stages, it is possible for some critical assumptions to end up as intermediary calculations later in the process of developing the methodology. For instance, if the elasticity of demand for a commodity is an exogenous input, the quantity demanded can no longer be among the critical assumptions. If it is, then the price of the commodity and the price elasticity of demand for the commodity must replace quantity as critical assumptions.

11. **Why are there no signs on checkmarks corresponding to transfers within the DC&S instrument?** Within the DC&S instrument, the checkmarks indicate whether a transfer is sensitive to a critical assumption or not. It is not necessary to indicate the direction of the sensitivity, so no sign is required.

12. **Are probability distributions and ranges always needed in the DC&S instrument?** A range of possible values is a necessity for all critical assumptions. Without such a range, having them listed as critical assumptions would be counterintuitive. However, having a Monte Carlo simulation is not always a part of a CBA. Even when Monte Carlo simulations are a part of the CBA, not all critical assumptions would need to be considered a source of variability in probabilistic analysis. A reason for considering a probability distribution as an optional part of this instrument is that design parameters are not a source of risk or variability. Therefore, they do not need a probability distribution.

13. **Are correlations always needed in the DC&S instrument?** No, it is not always necessary to specify correlations within the DC&S instrument. One can only specify a correlation between two sources of vulnerability.

14. **Why does each correlation appear twice in the DC&S instrument?** Correlations create dependencies between the movements of two sources of vulnerability. Both of these variables must be in the DC&S instrument, and the degree of correlation is the same irrespective of which end one considers. Therefore, the same correlation would show up once for each variable in a DC&S instrument.

15. **How to derive the probability distributions, ranges, and correlations?** Guidance on deriving sensitivity ranges, probability distributions, and correlations is beyond the scope of this article. However, to the degree possible, it is recommended to ensure that the mid-point (within a sensitivity range) and the expected value (within a

probability distribution) for a critical assumption are the same as the value used for deterministic analysis (base case).

3.4 Quantities & Values (Q&V) Instrument

UCBA relies on Q&V instruments to efficiently and comprehensively explain how costs, benefits, or transfers are calculated. There will be one Q&V instrument (typically structured as a table) for each benefit, cost, and transfer. When relevant, Q&V tables are also constructed for decision criteria in the DC&S instrument and dynamic timelines that appear in the Q&Vs for benefits, costs, and transfers. The Q&V tables specify the approach and methodology for a calculation. Each Q&V contains the following:

- A narrative describing the methodology
- Timeframe: the period(s) in which the calculation is relevant (only relevant to the main Q&Vs - those that specify a cost, a benefit, or a transfer)
- List of inputs (and their units)
- Calculations (the mathematical formulas)

The information within the Q&V tables should be able to stand alone from the rest of the report to facilitate an independent peer review of the approach to quantify and monetize a benefit, cost, or transfer, or to calculate a timeframe or decision criteria. The narratives are an essential component of the Q&V tables and should specify any assumptions made about the calculations and inputs. The narrative should also include references for any external sources (e.g., secondary data sources or sources of critical assumptions).[26]

The timeframe section is typically the shortest element of a Q&V table. Here, the analyst specifies the period in which the calculation of the benefit, cost, or transfer is relevant. Examples of periods for the CBA of an investment may include construction, ramp-up, operation, and closure (also called close-out).

The input section can include simple inputs that have a single value or an array or matrix that can take different values across one or more dimensions (such as a time series). At a minimum, **the inputs must include all of the critical assumptions from the DC&S instrument that are linked to the impact specified** in the Q&V. The formulas and calculations in a Q&V table should use all of the inputs listed in the same Q&V table. Ensuring consistency across the labeling of inputs - both in the different sections of the Q&V tables and across Q&V tables (if relevant) - is essential to ensure the tables are easy to follow.

For each input, a Q&V can also include a value and a source (citation). These two pieces of information are optional since the methodology can be specified comprehensively without

[26] This detailed approach addresses the call for CBA practitioners to specify the methodology and data sources they use to derive the estimates of variables. “The amount of detail provided should be sufficient to allow other researchers to replicate the estimates of economic values used in the study” (Dobes et al., 2016: 92).

input values. In practice, keeping even just the source but omitting the value can help in preparing methodologies - it forces the analyst to ensure data is available to execute the planned methodology but allows the analyst to submit the methodology for review without pre-populating the input values.

The calculation section contains a formula that brings together the inputs to calculate the benefit, cost, transfer, timeframe, or decision criteria specified in the Q&V.[27] Multiple calculations may be reported in a Q&V when an impact affects multiple perspectives. To determine if multiple calculations are needed, the analyst must **cross-check with the BC&P instrument and ensure that for every checkmark in front of the impact, there is a calculation** specified in the Q&V. The use of flags can be helpful to allow for the use of consistent formulas across periods of an investment; refer to Annex 2 for more detailed guidance on the use of flags.

Table 3.8 presents an example of the Q&V instrument frame.

Table 3.8. Q&V instrument frame

B1 - (the name of the benefit)					
Narrative					
To estimate Benefit 1, **inputs** X and Y are utilized under the Z **methodology** (citation as needed) to **quantify** the benefit. Furthermore, inputs A and B are utilized under the C methodology (citation as needed) to **monetize** this benefit. Further information about **perspective(s)** and **timeframe(s)** as necessary.					
Timeframe(s)					
Inputs		**Dimensions**	**Unit**	**[Value]**	**[Source]**
X	*Variable name*		#	*Value*	*Author, Year*
Y_p	*Variable name*	*Perspective*	%	*Annex #*	*Author, Year*
A	*Variable name*		%	*Value*	*Author, Year*
B	*Variable name*		USD	*Value*	*Author, Year*
$P_{R,G}$	*Variable name*	*Gender, Region*	#	*Annex #*	*Author, Year*
Intermediate Calculations					
Output	*Name (unit)*	*Formula*			
Final Calculations					
Benefit:	$B1 =$				

[27] According to Dobes et al. (2016: 106), "An analytically complete study should also record sufficient data and calculations to allow reviewers to check the validity of the conclusions. Replicability is an important means of ensuring the credibility of the results."

In **Table 3.8**, perspective is suggested as a dimension for input Y_p, where p denotes the dimension in the input name. Dimensions facilitate the introduction of single and multi-dimensional arrays as inputs. In this example, perspective is present as the dimension. Other common dimensions include time, region, gender, age group, and scenario.[28] Note that if a scenario is a dimension for an input, then the final calculation should also have the same dimension. An example of a multi-dimensional array is participants by gender and region ($P_{R,G}$), where R denotes region and G denotes gender. If the Q&V instrument includes the value column, the values of an array cannot fit in the Q&V instrument and must be reserved for an annex.

To summarize, Q&Vs must be internally and externally consistent based on the following criteria:

- Internal consistency
    a. Mathematical naming of the input (e.g., P_i) must be consistent between the inputs and calculation sections of the Q&V.
    b. The narrative must clearly explain every aspect of the process through which inputs are converted to the calculation(s) of impact.
    c. Every input needs a unit, but value and source are optional.
    d. Every input that appears in the Q&V must be used in at least one intermediate or final calculation.
    e. Every intermediate calculation must appear in at least one other intermediate calculation or the final calculation.
- External consistency
    a. There must be a Q&V table for every benefit, cost, and transfer in BC&P.
    b. There must be a final calculation for every BC&P checkmark (perspective) appearing on the same row as the specified benefit, cost, or transfer.
    c. All critical assumptions in the DC&S that have a checkmark for benefit, cost, or transfer must appear in the inputs section of the corresponding Q&V.

Figure 3.2 visualizes the external consistency requirements.

[28] For example, a scenario dimension could be used to distinguish between parameter values such as price_{optimistic}, price_{pessimistic}, and price_{most likely}.

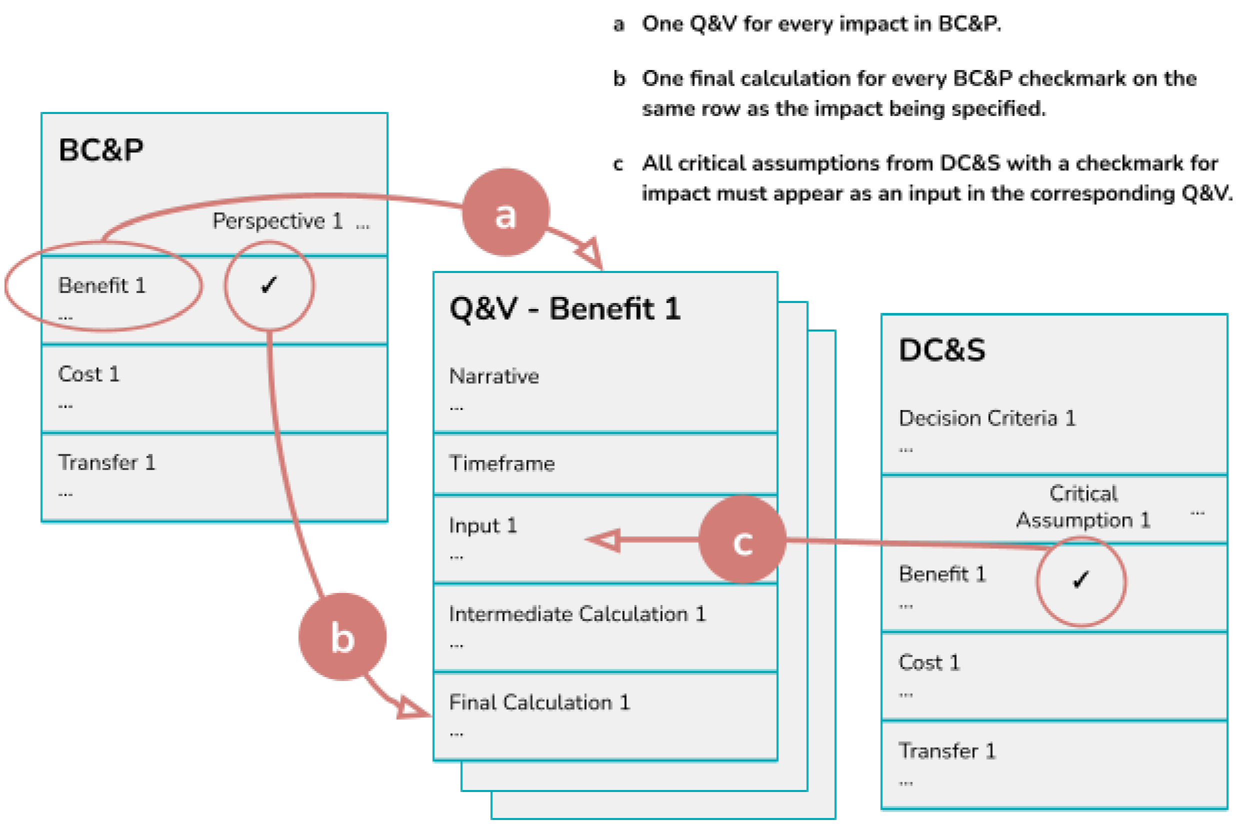

Figure 3.2 External Consistency Requirements across UCBA Instruments

Table 3.9 shows an illustrative Q&V for the second benefit of the electricity time of use campaign example: B2 - Reduced GHG emissions. According to the BC&S, this benefit only requires one calculation (from the country's perspective). Furthermore, the DC&P shows that the calculation of this benefit must utilize the "Effectiveness of the Campaign (%)" and the "Social Cost of GHG Emissions (2021)" among its inputs.

Table 3.9. Q&V instrument for the second benefit of the electricity time of use campaign example

B2 - Reduced GHG Emissions
Narrative
To estimate the amount of reduced GHG emissions in tonnes, the potential amount of electricity that can transition from peak generation to off-peak generation per customer per period is multiplied by the number of customers, the effectiveness of the campaign, and the difference in GHG emissions per kWh of electricity between off-peak and peak. To value this reduction, the total amount of emissions averted per period is then multiplied by the social cost of GHG emissions per tonne. Note that the potential savings and number of customers can differ by customer type (residential, commercial, and industrial). However, the campaign's effectiveness is expected to be the same across all customer types.
Timeframe(s)
Anticipated Period of Effect

Inputs		Dimensions	Unit	Value	Source
T_i	*Potential per customer of peak energy to off-peak energy transition per year*	*Type*	*kWh*	*Annex 1*	*[Author, Year]*
Q_i	*Number of customers*	*Type*	*#*	*Annex 1*	*[Author, Year]*
E	*Effectiveness of the campaign*		*%*	30%	*[Author, Year]*
γ	*GHG emissions differential per kWh*		*tonnes*	0.003	*[Author, Year]*
c^{GHG}	*Social cost of GHG emissions per tonne*		2021 USD	$100	*[Author, Year]*
Intermediate Calculations					
Q^{GHG}	*Volume of emissions averted per year (tonnes)*	$Q^{GHG} = E \times \gamma \times \sum_{i}^{n}\left(T_i \times Q_i\right)$			
Final Calculations					
Benefit:	$B1_t = Q^{GHG} \times c^{GHG}$				

Practical Considerations

16. **If an input is introduced in a Q&V, does it need to appear in the following Q&Vs?** Inputs used in multiple Q&Vs must be presented in each of those Q&Vs. An analyst should NOT exclude an input from a Q&V just because it was introduced in an earlier Q&V. A Q&V must remain auditable in isolation.

17. **Can there be multiple Q&V instruments?** There must be a Q&V instrument for each benefit, cost, or transfer identified in the BC&P. Moreover, the Q&V instrument is a meta table, meaning there will be multiple instances of it over the course of the CBA.

18. **Is the Q&V instrument limited to the benefits, costs, and transfers in the BC&P instrument?** The Q&V instrument applies to - but is not limited to - the benefits, costs, and transfers noted in the BC&P instrument. Practitioners may utilize a Q&V instrument to document the approach to calculate decision criteria and for complex timeframes that are dynamically calculated (such as defining the construction period as a function of the start date, expected duration of construction, and the time-overrun as three independent exogenous inputs).

19. **Is there a limit on the length of the Q&V instrument?** It is recommended that a single Q&V instrument, often presented as a table, take at most one page. Q&V instruments can be longer. While having a two-page Q&V instrument remains acceptable, this might be a sign of overcomplication. There are two ways to reduce the size of the Q&V instrument. First, there might be scope to break down the instrument into two or more Q&V instruments. For instance, instead of health benefits, one can define two separate benefits: reduction in premature mortality and reduction in morbidity. Second, some of the calculations may deserve to be

independent annexes or research papers that can be then cited in the Q&V. For instance, if a regression is made on primary data to estimate the average wage, the regression analysis and the underlying data do not need to be part of the CBA specification. They can appear as an annex or a separate research paper.

20. **How to break complex formulas?** When a formula is complex and does not fit in a single line, adding intermediate formulas above the calculation row is useful. For example, quantifying the impact can be a separate intermediary calculation in the Q&V, which is then used in the final formula that values the total impact.

21. **Are there any tips for the mathematical naming of inputs?** Recommended naming conventions include keeping input names as short as possible (one letter where possible), using subscripts (comma separated) to denote dimensions, and using superscripts to concisely add more information to the name (e.g., with (w) and without (w/o) are common superscripts). Similarly, superscripts can be used to distinguish benefit, cost, or transfer flows for a specific perspective (for example, $B1^{Youth}$ from $B1^{Adult}$). Note that superscripts function as part of the variable name, and should not correspond to a dimension.

3.5 Inputs Instrument

The practitioner identifies all inputs within the Q&V instruments (an exception to this is when the baseline discount rate or other similar assumptions are only present in the DC&S instrument). It is common to have an input repeated in multiple Q&Vs. As noted above, the practitioner may or may not specify input values within the Q&Vs. Therefore, UCBA requires a fourth and final instrument - the inputs instrument - to consolidate inputs for application within the CBA model.

UCBA requires that the inputs instrument consist of a list of unique inputs, their values, and the source of this information. For each input, the instrument needs to specify:

- The name of the input, which should be the same as the name in the inputs specified in the Q&V tables;
- The input's value;
- The source of information (for example, the author and year of the underlying administrative data, performance evaluation report, impact evaluation report, academic literature); and,
- For ex-ante analysis, the input instrument can also include a suggested means for ex-post verification (for example, accounting data for cost assumptions, administrative data for performance, and impact evaluation for impact).

Like Q&Vs, the inputs instrument might consist of multiple tables. It is recommended practice to:

- Gather all "simple inputs" in one table.
- Aggregate "single-dimension inputs" across dimensions and create a table for each dimension.
- Create a separate table for each of the "multi-dimensional inputs."

Dimensions are any attribute that converts a single value into an array of values. Examples of dimensions include:

- Time: The value of a variable can differ from one period to another (time series).
- Perspective: The same benefit can have different values from different perspectives.
- District: The value of a parameter can differ from one geographic or administrative district to another.

Dimensions are commonly given a single-letter identifier and appear as a subscript after the variable name (B_t or F_d, where t and d are time and district, respectively). One variable can have multiple dimensions. For instance, the price of electricity by district in each time period is $p_{t,d}$.

Tables 3.10 to 3.15 show templates and examples of the input instrument for simple, single-dimension, and multi-dimension inputs. Please note that after the second dimension, each new dimension will only increase the number of sub-tables included in the instrument.

Table 3.10. Inputs instrument (simple inputs)

Input name	Value	Unit	Source
Input name	##	Unit	Citation
...	...	...	...

Table 3.11. Simple inputs for the electricity time of use campaign example

Input name	Value	Unit	Source
Effectiveness of the campaign	30%	%	[Citation]
GHG emissions differential per kWh	0.003	Tonne	[Citation]
Social cost of GHG emissions per tonne	$100	2021 USD	[Citation]

Table 3.12. Inputs instrument (simple dimension: time)

Input name	Unit	Period 1	Period 2	...
Input name[1]	Unit	Value 1	Value 2	...

Input name	Unit	Period 1	Period 2	...
...	...	...	...	...
Sources				
1: Citation ...				

Table 3.13. Simple dimension inputs (customer type) for the electricity time of use campaign example

Input name	Unit	Residential	Commercial	Industrial
Potential peak to off-peak transition per year[1]	kWh	100	200	2000
Number of customers[2]	#	200,000	1,000	500
Sources				
1: [Citation] 2: [Citation]				

Table 3.14. Inputs instrument (two dimensions: time and region)

Input name	Unit	Period 1	Period 2	...
Region 1				
Input name[1]	Unit	Value 1	Value 2	...
...	...	...	...	...
Region 2				
Input name[2]	Unit	Value 1	Value 2	...
...	...	...	...	...
...				
Sources				
1: Citation 2: Citation ...				

Table 3.15. Inputs instrument (three dimensions: health outcome, gender, and province)

Input name	Unit	Low Birth Weight (LBW)	Pre-Term Birth (PTB)	...
Ontario				
Prevalence of health outcome for women[1]	%	2.00%	2.00%	...
Prevalence of health outcome for men[1]	%	2.00%	2.00%	...
Quebec				
Prevalence of health outcome for women[2]	%	2.00%	2.00%	...
Prevalence of health outcome for men[2]	%	2.00%	2.00%	...
...				
Sources				
1: Citation 2: Citation ...				

Practical Considerations

22. **Where to construct the inputs instrument?** Suppose a spreadsheet is used to implement the CBA model. In this case, it is good practice to set up the inputs instrument (and all component tables) in the same workbook that will operationalize the calculations from Q&V instruments. Doing this will make connecting the calculations tables (implementation of Q&Vs) to the relevant inputs easier. Keeping all Q&V and inputs tables within one workbook is also practical since a single input may be used in the calculation of multiple Q&V tables.

23. **What is the advantage of using dimensions if a dimension has only two or three values (for example, age groups can have two values, children and adults)?** Dimensions can simplify the specification of CBA models. **Table 3.16** shows an example of how the specification of a simple calculation can be shortened using dimensions across the specification instruments.

Table 3.16. Illustrative example: without dimensions vs. with dimensions

	Without Dimensions	With Dimensions
Inputs in Q&V	• Women customers (C^f) • Men customers (C^m) • Fee for women (p^f) • Fee for men (p^m)	• Customers by gender (C_g) • Fee by gender (p_g)

<table>
<tr>
<td>Calculations in Q&V</td>
<td>

Sales to women ($S^f = C^f \times p^f$)
Sales to men ($S^m = C^m \times p^m$)
Total sales ($S = S^f + S^m$)

</td>
<td>

Sales by gender ($S_g = C_g \times p_g$)
Total sales ($S = \sum_g^n (C_g \times p_g)$)

</td>
</tr>
<tr>
<td>Inputs</td>
<td>
<table>
<tr><td>Women customers</td><td>##</td></tr>
<tr><td>Men customers</td><td>##</td></tr>
<tr><td>Fee for women</td><td>$##</td></tr>
<tr><td>Fee for men</td><td>$##</td></tr>
</table>
</td>
<td>
<table>
<tr><td></td><td>Women</td><td>Men</td></tr>
<tr><td>Customers</td><td>##</td><td>##</td></tr>
<tr><td>Fee</td><td>$##</td><td>$##</td></tr>
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3.6 A Note Before Modeling

The UCBA instruments can be most useful when analysts construct them before building a model, in whichever system, software, or format the model is constructed. This requires the analyst to obtain and review the data needed for the inputs instrument, as methodological choices will depend, *inter alia*, on the type of data that is available. Having critical data inputs in hand allows for adjustments to the UCBA instruments without costly retro-fitting of the model.

4. Discussion and Conclusions

The UCBA paradigm offers a structured yet practical approach to resolving several challenges facing CBA practitioners. Notably, the UCBA paradigm does not impose a specific methodology for the conduct of CBA. In this way, UCBA responds to the calls within the literature for a more coherent approach to the conduct of CBA (Dobes et al., 2016; Robinson et al., 2019).

The use of UCBA may entail a shift in approach for practitioners, but it does not fundamentally challenge the existing practice of CBA. UCBA is consistent with and adaptable to many of the established practices of CBA, including integrated analysis and incremental analysis. Specifying a CBA using UCBA requires knowledge of the conventions and the logical linkages described by this paper. However, since UCBA only frames narratives in human language and mathematical notation in tabular formats, knowledge of UCBA is not required to supervise or review the work of a CBA analyst who uses UCBA.[29]

4.1 UCBA and Integrated Analysis

The approach to CBA as taught in some universities and graduate-level programs[30] incorporates alternative perspectives (stakeholders) using a stepwise process: Practitioners construct a financial model of the decision, expand the financial CBA into an economic CBA using conversion factors or other means, and allocate externalities (i.e., the difference between economic and financial impacts) to other stakeholders.

Within UCBA, the integrated approach emerges from the BC&P instrument. To explicitly demonstrate the integrated analysis, practitioners may adapt the BC&P instrument to their purposes: They may build the first column (a financial perspective), build out the last column (overall perspective, typically the economy), and then populate the columns in between by focusing on the distribution of externalities. Since UCBA tables are developed iteratively, the UCBA notation can specify a CBA that adheres to the integrated approach. Therefore, UCBA in no way conflicts with the conventional approach to conducting an integrated analysis.

4.2 UCBA and Incremental Analysis

The majority of CBA models (correctly) assess the incremental impacts of a decision. To do so, practitioners construct a counterfactual scenario (the 'without' or business-as-usual scenario) and compare it to the decision scenario (the 'with' scenario or the scenario in which the decision has been implemented).

[29] Evident is Limestone's reliance on UCBA for all of its CBAs without requiring its clients to learn the paradigm despite being technically engaged in reviewing the methodology, analysis, and results.
[30] Such as within the courses offered at Duke University and Queen's University.

From a practical perspective, UCBA focuses on the impacts of an intervention. Each impact (cost, benefit, or transfer) must capture or encapsulate the 'with' and 'without' scenarios and report the difference. There is, therefore, no methodological conflict between the UCBA paradigm and the incremental approach to CBA. The Q&V instruments can explicitly calculate a project's costs and benefits of an intervention to an ongoing operation under the 'with' and 'without' scenarios. However, the Q&V must ultimately report the intervention's benefit or cost on an increment

al basis. The other projections under the 'with' and 'without' scenarios can inform specific decision criteria in the DC&S instrument. Despite this compatibility, practitioners used to the stepwise 'with' and 'without' approach may initially find it difficult to define benefits and costs based on the incremental impacts and then arrive at projections under the 'with' and 'without' within each impact channel.

To illustrate, consider the estimation of the benefits of a transport intervention that results in cars travelling at higher speeds. In the stepwise 'with' and 'without' approach, the analyst estimates the total net cost of travelling without the intervention, then the total net cost of travelling with the intervention, and finally compares the two. In the UCBA approach, travel time savings and vehicle operating cost savings are defined as benefits. The 'with' and 'without' values for each of these items must be considered within the calculation of each benefit, such that the savings - the difference between the 'with' and 'without' costs - can be reported.

While the UCBA paradigm focuses on each impact of a decision or intervention, the cumulative result is the net incremental impact - precisely the objective of the stepwise 'with' and 'without' approach. The difference between these two approaches is more about semantics and what the practitioner is used to than any fundamental consideration.

4.3 Contributions and Implications for Future Research

This article significantly contributes to the practice of CBA by proposing a paradigm to address and resolve several challenges facing CBA practitioners. The ability of UCBA to flexibly adapt to any CBA across sectors and calculation methodologies means it can improve the transparency and auditability of any CBA. Adopting the UCBA paradigm and its component instruments by CBA practitioners can help reduce the costs of executing such analysis and expand the practice of CBAs across more policies and investment decisions.

The implications of this article are several. To advance the practice of CBA, the editors, readers, and contributors to the *Journal of Benefit-Cost Analysis* might begin to apply UCBA in preparing and delivering their analyses. Once sufficient analyses are documented within the UCBA paradigm and speak a common language, there may be opportunities for machine learning to build upon and refine these practices. Such innovation could allow CBA practitioners to focus on conceptualizing and reviewing models, reserving their preparation according to the UCBA paradigm for technology-assisted automation.

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Annex 1: Impacts and Perspectives

Impacts and Perspectives

According to the principles of UCBA, impacts of the decision, policy, project, or investment can be costs, benefits, or transfers. Each impact must affect at least one perspective.

Consider a project that affects two perspectives: (1) a public utility, saving on its cost of electricity generation - B1, and (2) consumers, benefiting from improved reliability - B2. These benefits do not come for free. The public utility needs to invest in better infrastructure (C1), and consumers need to change their equipment (C1) and pay a higher price to the public utility (T). **Figure A1.1** illustrates these relationships.

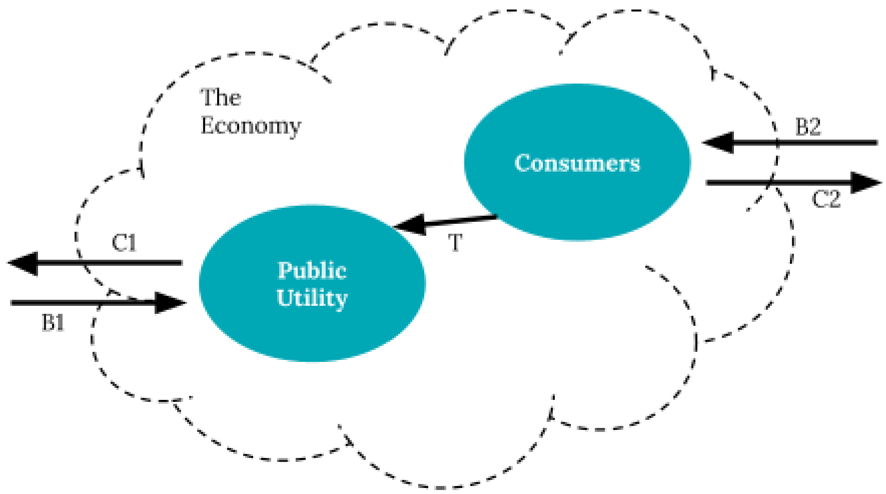

Figure A1.1. Impacts and perspectives in UCBA

In this example, the net impact on the public utility, the consumers, and the economy/society is estimated as shown below.

$$\text{Net impact on public utility} \quad B1 - C1 + T$$

$$\text{Net impact on consumers} \quad B2 - C2 - T$$

$$\text{Net impact on the economy/society} \quad B1 + B2 - C1 - C2$$

Perspectives can vary from one CBA to another. The number of perspectives depends on the nature of the project or policy being evaluated by the CBA and the questions the model needs to address. Perspectives can also overlap by definition. For instance, a project's female beneficiaries can overlap with its beneficiaries who are ten years of age or younger. While reporting the net impact on both might be important, it is critical not to add up and thereby double-count the impact on these two perspectives when reporting the aggregate impact.

Perspectives in the Integrated Approach to CBA

Financial actors & non-financial actors

Many institutions have traditionally focused on estimating the net economic impact of the project, such as the World Bank's reliance on the economic NPV (ENPV) and the Millennium Challenge Corporation's (MCC's) consideration of the economic IRR (ERR). However, the demand for reporting the impact from specific perspectives, such as targeted beneficiaries or investors, has increased over the years. Some institutions have come up with additional names for such analysis, including "risk analysis" (Inter-American Development Bank), "stakeholder analysis" (USAID), and "beneficiary analysis" (MCC). Multi-perspective financial analysis has also gathered renewed attention in recent years as partnerships with the private sector and other economic agents, such as farmers, have gained popularity. Analyzing the distribution of financial and non-financial impacts of the decision from different perspectives is, therefore, explicitly allowed for within UCBA.

In practice, the terms used to describe impacts from different perspectives can differ from one model to another. The following conventions are followed in UCBA to avoid confusion:

- Financial actor: Any actor who needs to make a DIRECT[31] financial contribution to operationalize the decision (investment or policy) WITH or WITHOUT the expectation of a financial gain.
- Non-financial actor: Any actor who may receive non-financial[32] or INDIRECT financial impacts (costs or benefits).

The term "economic"

The term "economic" in the area of international development is perceived as the overall impact on all the agents in the economy, including financial and non-financial costs and benefits, but excluding transfers such as taxes and subsidies. At NGOs and engineering firms, the term "economic" is often interpreted as "financial." For the purposes of UCBA, the terms social and economic mean the same thing: the aggregate impact of a transaction or the net aggregate impact of a project on all stakeholders, including the financial and non-financial actors.

In the most basic form, all of these actors are in the same economy and the economic (social) impact is the aggregate impact on all of these actors. **Figure A1.2** illustrates this

[31] Grants are an example of a DIRECT financial contribution. Taxes and subsidies are examples of INDIRECT financial impact (to the government).
[32] Non-financial impacts include, but are not limited to, safety, education, nutrition, and health.

relationship. In such an accounting framework, transfers are a cost for one party and a benefit for another, making their net economic (social) impact equal to zero.

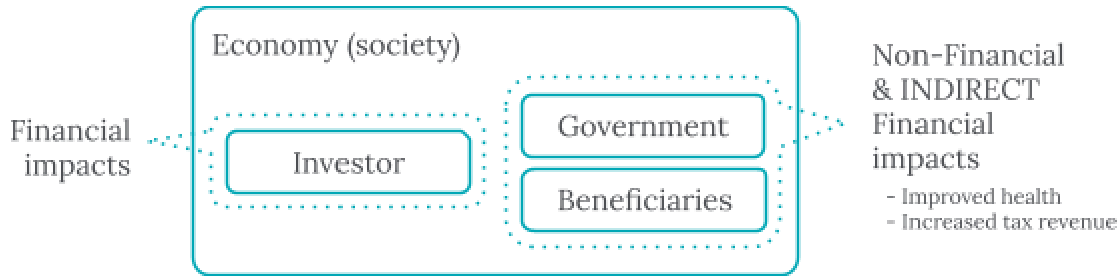

Figure A1.2. An example of alternative perspectives

There are situations in which the definition of these actors may not be as straightforward. Some of these situations are discussed below.

In the case of financial partnerships (multiple financial perspectives)

When other actors, not just the investor, are assumed to take part in paying DIRECTLY for the costs of the project with the expectation of some DIRECT financial benefits, they become an additional financial actor. An example is the public utility that off-takes the power produced by an independent power producer (IPP) and sells it to final consumers after paying for the costs associated with transmission and distribution. For the final consumers of energy to realize the benefits of such a project, the operation must be financially sustainable for both the IPP and the public utility.

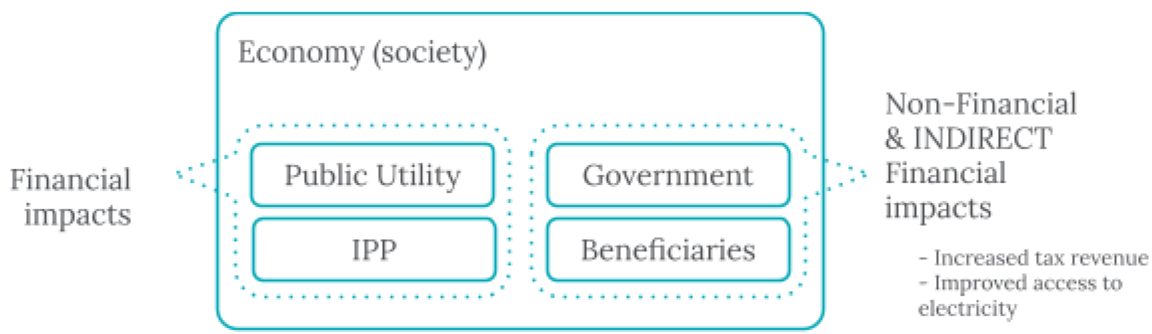

Figure A1.3. An example of multiple financial perspectives

In the case when financial sustainability for beneficiaries matters

In some instances, the party that is required to pay DIRECTLY for some of the costs may receive both DIRECT and INDIRECT benefits from the intervention. A typical example is when farmers are expected to incur some costs and adjust their operation in the expectation of increased financial benefits along with improved health and education. Under such circumstances, the impacts on such actors must be split between financial and external. This separation allows to conduct a meaningful financial analysis that reflects the decision-making structure of the farmer, which is primarily based on the DIRECT financial costs and DIRECT financial benefits.

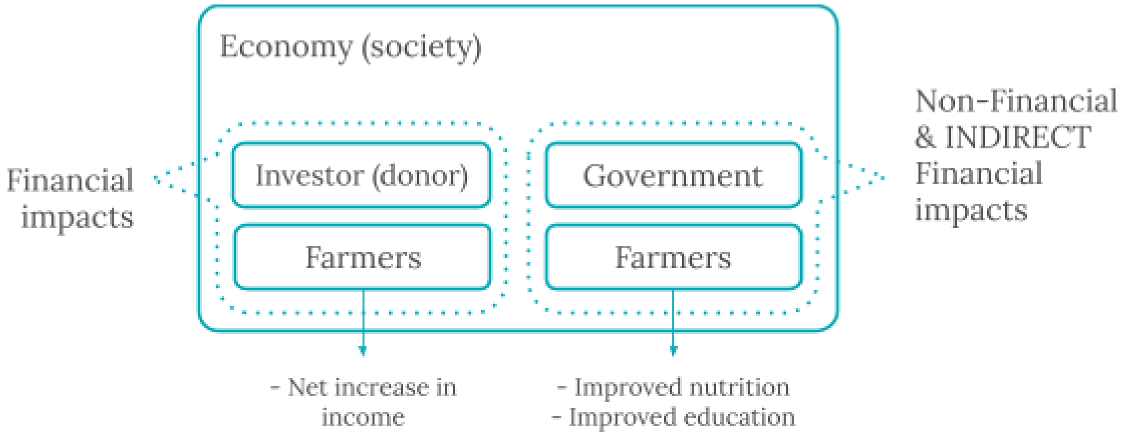

Figure A1.4. An example of a perspective with financial and non-financial impacts

In the case when multiple countries are involved (global perspective)

The analysis of projects may need to consider the impacts on more than one economy. Having multiple economic perspectives is relevant for international transport and transmission projects. When projects are defined at a regional level simply for their institutional scale, the analysis must be conducted separately for each country. Another example of when having multiple economic perspectives is justified is when a project is expected to leave a significant impact on one or more markets in another economy.

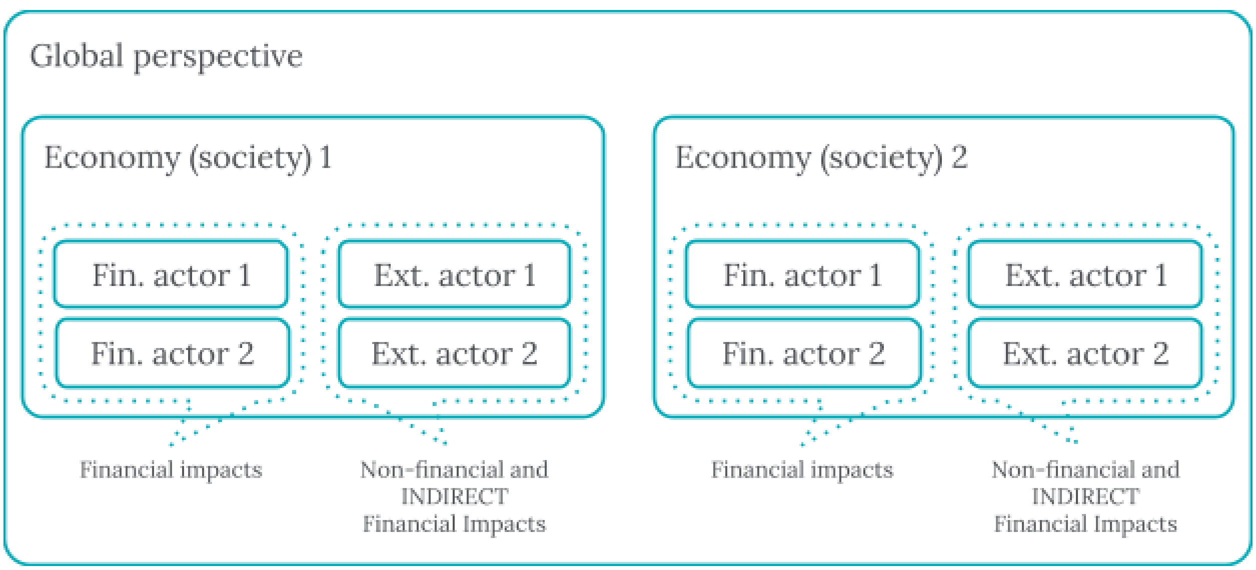

Figure A1.5. An example of multiple economies and a global perspective

Some examples

- **Grant Financing:** USAID implements the construction of a water treatment plant. Note that this example does not change if USAID provides a grant to an NGO to implement the project, in which case USAID will simply hire the NGO to deliver the project.

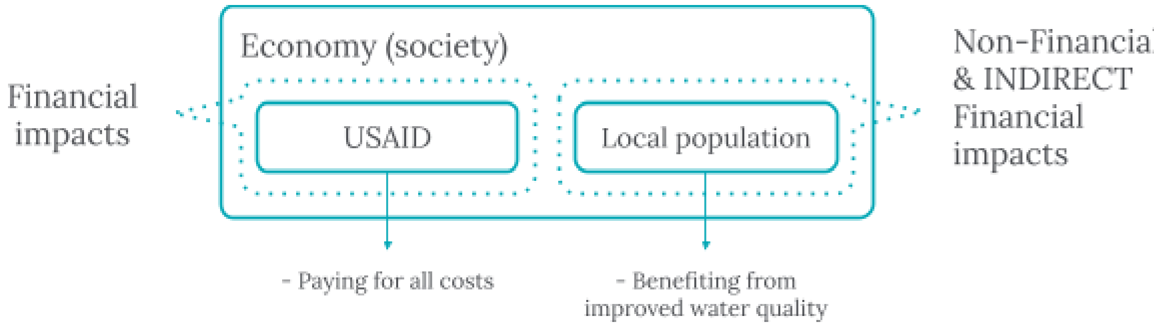

Figure A1.6. An example of perspectives when USAID funds the construction of a water treatment plant

- **Blended Finance:** USAID partially finances the construction of a water treatment plant in the form of a grant. The plant operator provides the rest of the funds required in the expectation of revenue from water sales. In this scenario, the operator will pay taxes to the government.

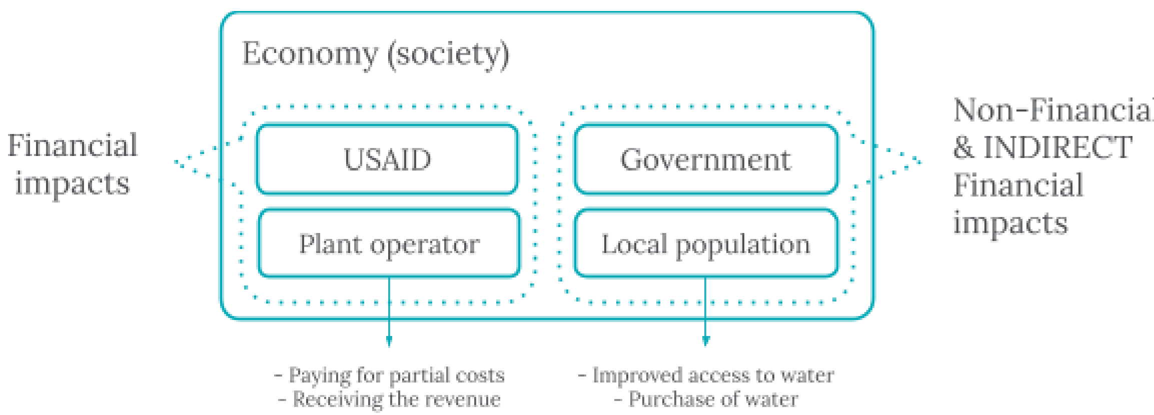

Figure A1.7. An example of perspectives in blended financing

- **Results-Based Financing:** USAID pays an NGO conditional on the successful implementation of an intervention (based on pre-agreed results). The NGO might use its own funds or raise equity from investors.

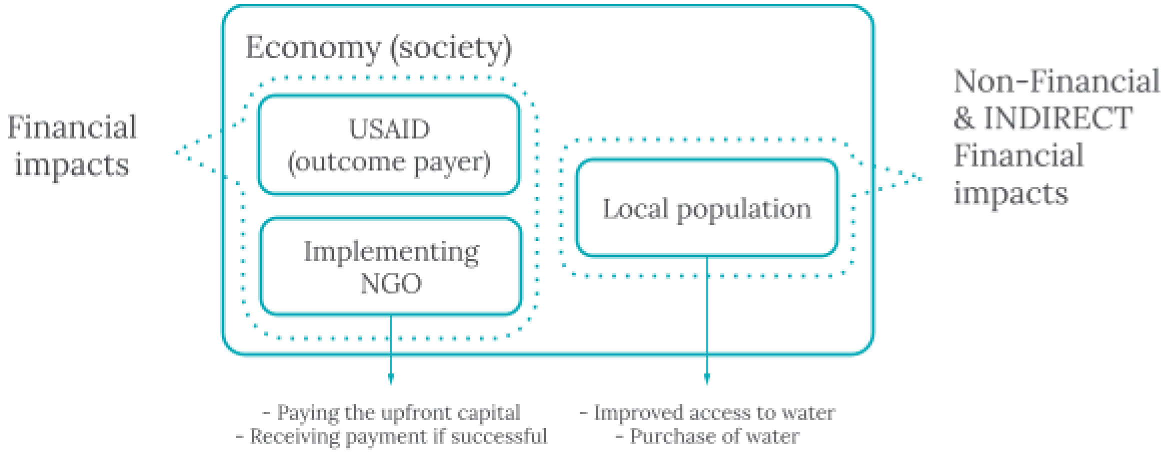

Figure A1.8. An example of perspectives in results-based financing

- **Environmental Analysis:** A policy will have environmental impacts, specifically reductions in greenhouse gas (GHG) emissions. The domestic or national perspective will accrue benefits using the own-country social cost of carbon. Benefits may also accrue to the global perspective, which is inclusive of the domestic or national perspective (i.e., representing the impacts on all other countries as well as the domestic or national perspective). The benefit to the global perspective should be calculated using the global value of the social cost of carbon, which includes the country-specific social cost of carbon. Note that this subtlety may require narrative to clarify the two perspectives and the decision-making implications of results for each.

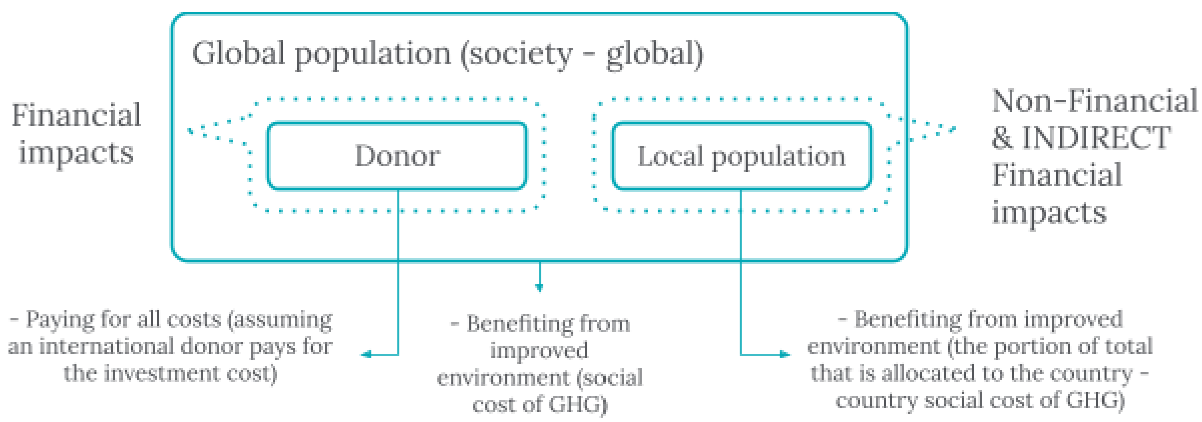

Figure A1.8. An example of perspectives in environmental analysis

There can be a scenario where some form of payment is made by other countries (or regions) to the country (or region) that takes actions that result in aversion of GHG emissions. These transactions can be under carbon credit programs. Such financial transactions will not affect the impact discussed here and only enter the analysis as a transfer in the UCBA framework. In this scenario, the analyst must add a new perspective that represents the payer of such transfer (e.g., other countries) to the analysis to correctly integrate such transactions.

Annex 2: Documentation Conventions

This annex presents documentation conventions used at Limestone for operationalizing UCBA - when transforming the instruments into a functioning CBA model - to allow for teamwork and consistent reporting. Practitioners can adopt these conventions to analyze a range of policies and investments across various spreadsheet platforms (e.g., Excel, Google Sheets).

Flags

Within UCBA, flags are used to operationalize time frames in the formulation of a CBA model. The use of flags serves to simplify the estimation of time series for benefits, costs, and transfers. Flags are time series themselves, but their role is to denote the timeframes relevant to a project or policy by having a value of one (1) for the relevant periods and zero (0) otherwise. For instance, if there are only two relevant timeframes for a project - investment and operation - then the analysis requires two flags: investment flag and operation flag. See **Table A2.1**.

Table A2.1. Examples of flags

Period	2018	2019	2020	2021	2022
Investment flag	1	0	0	0	0
Operation flag	0	1	1	1	0

Flags are used in the model to simplify formulas. For instance, imagine that we know a particular benefit is valued at $200, but it is only delivered during the operation period. By using flags, a modeller can simply apply a formula that multiplies the “operation flag” with the input value (200) in all time periods. This flag allows the modeller to maintain a consistent formula across the project life.

Flags can be calculated using formulas as well, which is useful to test how sensitive the results are to assumptions around the timing of the project, such as construction delays. In such a case, the timeline is dynamic or flexible and the calculation of its flag would require its own Q&V table. **Table A2.2** presents an example of flag calculation.

Table A2.2. Example of investment flag calculation

A	B	C	D	E	F	G
1	Start year	2018				
2	Duration of investment	2				
3	Period	2018	2019	2020	2021	2022
4	Investment flag (formula)	=if(C3<C1+C2, 1, 0)	=if(D3<C1+C2, 1, 0)	=if(E3<C1+C2, 1, 0)	=if(F3<C1+C2, 1, 0)	=if(G3<C1+C2, 1, 0)
5	Investment flag (output)	1	1	0	0	0

Note that the way flags enter the formulas in a calculation block within a spreadsheet does not need to be documented in the formulas that appear in the Q&V tables of benefits, costs, and transfers. Those Q&V tables include a "timeframe" box that specifies the relevant timeframe(s). When more than one time frame is specified, then the Q&V table must show different formulas for each applicable timeframe in the calculation section of the Q&V. Therefore, there is no need to include flags as an input or inside intermediate or final calculations within a Q&V.

Larger or More Complex CBA Models

Limestone analysts typically implement models in spreadsheet-based programs such as Google Sheets or Microsoft Excel, using calculation blocks to execute the calculations stipulated in the Q&Vs. Limestone recommends the following techniques to ensure that spreadsheet-based models remain manageable, auditable, and are less vulnerable to errors in programming:

- **Abide by recommended limits on the size of a Q&V (no more than one page or "view") and the size of a spreadsheet-based model (no more than 1,000 lines).** A major advantage of constructing shorter Q&Vs is to ensure that each calculation block is also short in a way that can then be visually inspected in a single "view" within the spreadsheet. To keep Q&Vs shorter,
    - Search for efficiencies in the Q&V (Are all intermediate calculations required to be standalone calculations? Can dimensions be introduced that allow for presenting equations in a more streamlined manner?);
    - Separate a very large Q&V into multiple smaller Q&Vs with a corresponding expansion of the BC&P to reflect the additional impacts; and/or
    - Use annexes to remove material including intermediary calculations of inputs to sit outside of the Q&Vs. Note that inputs introduced within an annex cannot be the subject of sensitivity analysis.

  Another benefit of shorter Q&Vs is that they should yield shorter calculation blocks and models, helping analysts to limit spreadsheet-based models (specifically the calculation blocks that are typically presented on a single "calculations" or "model" sheet) to no more than 1,000 lines in length. This is important because models of larger size become less efficient, more complex to update or amend, and more difficult and costly to audit.

- **Complete the UCBA instruments - including obtaining the data needed for the inputs instrument - <u>before</u> building the calculation blocks.** Having critical data inputs in hand allows for adjustments to the UCBA instruments without costly retro-fitting of the calculation blocks and results dashboard. If a client insists on the construction of a CBA model before data is in hand, advise the client of the possible need for additional model revisions (and corresponding level of effort) should data ultimately not be available in the anticipated form.

- **Confirm that the outputs from the Q&V and calculation blocks that form the model only report what is required per the DC&S.** Remove any outputs that are not needed from the model and dashboard. For example, consider whether the full time-series (projections) of impacts must be presented or only the PV of those impacts.
- **Where possible, calculate aggregate projections once and disaggregate the projections using proportions.** This approach helps avoid repeating the same calculation for multiple levels of disaggregation. A client request for impacts to be disaggregated across multiple dimensions (e.g., gender, geography, poverty classification, firm type) will balloon the number of intermediate calculations and outputs from a model. When disaggregated inputs are not likely to be available (e.g., willingness to pay, health benefits, or educational impacts by gender, geography, and poverty classification), propose using a population-average value for these parameters and assigning a share of the total impact disaggregated by relevant shares of the population per category (e.g., gender, geography, and poverty classification). Discuss with the client the tradeoff between the possible loss of accuracy in the CBA model and the improved efficiency in building and auditing the CBA model.
- **If a model has become too large or overly complex, consider whether it is worth revising the model to reduce size or complexity.** If yes, estimate the level of effort needed to make these revisions and propose that request to the client.
- **Construct dashboards to include only the necessary information.** To optimize usability, construct dashboards that can be visually inspected in a single "view" within the spreadsheet. Where disaggregation is required, use either a dedicated sub-section (e.g., "Stakeholder Analysis") or use line grouping to strategically present disaggregated results and outputs from the CBA on the dashboard.

Annex 3: An Example

This annex provides an example spanning all four instruments that are required for a CBA produced under the UCBA paradigm. This example considers a public health intervention to reduce soil-transmitted helminth (worm) infection rates among children under five. An international non-governmental organization (INGO) implements this public health intervention in cooperation with a national government, which also provides a partial financial subsidy for deworming medication.[33]

Benefits, Costs, & Perspectives Instrument

Table A3.1. Benefits, costs, & perspectives for child deworming intervention

Impacts	Children Under Five	School-Aged Children	INGO	National Government
B1 - Reduction in wasting	✓			
B2 - Reduction in stunting	✓			
B3 - Reduction in anemia	✓	✓		
C1 - Cost of deworming medication			✓	
C2 - Cost of shipping medication			✓	
C3 - National administrative costs of distribution				✓
T1 - Subsidy of deworming medication cost			✓+	✓-

Note the following:

1. Benefits, costs, and transfers are identified using numbered Bs, Cs, and Ts.
2. A check mark relates an impact to a perspective.
3. An impact may relate to multiple perspectives.
4. Transfers must relate to at least two (2) perspectives.
5. Transfer check marks denote the transfer direction using + and - signs.

Decision Criteria & Sensitivity Instrument

Table A3.2 presents the DC&S instrument for the childhood deworming intervention. Note that as the intervention is single-year, all costs are incurred in the first year of operation, so the discount rate has no implications for costs. Costs incurred by the INGO and direct

[33] This example is based on a CBA conducted by Limestone Analytics under the Citrus collaboration. It has been modified for instructional purposes and streamlined for presentation purposes.

costs of deworming medication were considered reliable and not subjected to sensitivity analysis. For simplicity's sake, no probabilistic analysis is specified in this example.

Table A3.2. Decision criteria & sensitivity instrument for child deworming intervention

Decision Criteria					
• **Criteria: NPV, IRR, MIRR, BCR, cases of disease/condition averted, lives saved/cases of mortality averted, DALYs averted, cost per DALY averted** • **Visuals: composition of impacts cumulative waterfall chart, composition of impact by perspective waterfall chart**					
Critical Assumptions	**Discount rate (%)**	**Proportion of medication lost in delivery (%)**	**Dosing per course of treatment (#)**	**Anemia disability weight (#)**	**National administrative cost per person ($)**
B1 - Reduction in wasting	✓	✓	✓		
B2 - Reduction in stunting	✓	✓	✓		
B3 - Reduction in anemia	✓	✓	✓	✓	
C1 - Cost of deworming medication					
C2 - Cost of shipping medication					
C3 - National administrative costs of distribution					✓
T1 - Subsidy of deworming medication cost					
Range for sensitivity analysis	3% - 15%	10% - 50%	Single (1) or Multiple (3)	0.004 - 0.050	$0.28 - $28.00

Quantities & Values Instruments

Table A3.3 presents an illustrative Q&V instrument for the childhood deworming intervention. The impact of focus is B3: Reduction in Anemia, which spans multiple perspectives (groups). The project is a single-year implementation, so the calculation does not repeat over time.

Table A3.3. Q&V instrument for child deworming intervention

B3 - Reduction in anemia
Narrative
Abundant evidence indicates that STH infections, particularly hookworm, increase the prevalence of anemia. The nutritional impacts are primarily a concern in younger children due to the importance of nutrition

during their growth phase of life, but the increased prevalence of anemia is a concern for two particular groups: **pre-school-aged children (PSAC)** and **school-aged children (SAC)**.

This benefit uses the number of tablets shipped per each of the two medication types (**Albendazole** and **Mebendazole**) and the appropriate dosage for that type. To determine which group was treated, we use the reports provided by the INGO and assign the number of people treated to either PSAC or SAC.

Next, the appropriate change in risk of anemia is applied to the existing prevalence (Stevens et al., 2022) to determine the cases averted according to the degree of severity: **mild**, **moderate**, and **severe**. The relative risk of anemia for treated individuals vs. untreated individuals is taken from Salam, Das, and Bhutta (2021), Smith and Brooker (2010), and Bauleni *et al.* (2022). Once the cases averted are determined, the present value (PV) of the length of effect and the disability weight obtained from the 2019 GBD are used to determine the disability-adjusted life years (DALYs) averted. We assume that anemia only decreases until reinfection occurs. According to INGO documentation, treatment is recommended twice annually, implying that reinfection is expected to occur approximately every six months. We thus assume the length of effect is six months. The DALYs are then monetized using the VSLY.

Timeframe(s)

Project Dependent

Inputs		Dimensions	Unit
W	*Proportion of medication lost in delivery*		%
TW	*Proportion of treatments left incomplete*		%
ND_m	*Number of doses sent by INGO*	*Medication*	#
NT_m	*Number of doses per person for full course of treatment*	*Medication*	#
PG_g	*Proportion of group treated*	*Group*	%
$PR_{g,s}$	*Prevalence of anemia by group and severity*	*Group, Severity*	%
$RR_{g,s}$	*Relative risk of anemia by group and severity*	*Group, Severity*	%
DW_s	*Disability weight by severity of anemia*	*Severity*	#
LoE	*Length of deworming treatment effect*		#
D	*Discount rate*		%
$VSLY$	*Value of a statistical life year*		USD

Intermediate Calculations

Population treated, total:	$PT = \sum_{medication\ (m)}^{n} \left(\frac{ND_m \times (1-W)}{NT_m}\right) \times (1 - TW)$
Population treated, by group:	$PT_g = PT \times PG_g$
Cases averted by group and severity:	$CA_{g,s} = \left(PT_g \times PR_{g,s} \times \left(1 - RR_{g,s}\right)\right)$
DALYs averted by group and severity:	$DALY_{g,s} = CA_{g,s} \times PV\left(DW_s, LoE_s, D\right)$

Final Calculation

$$\text{Benefit:} \quad B3 = \sum_{group\ (g)}^{n} \left(\sum_{severity\ (s)}^{n} \left(DALY_{g,s} \times VSLY \right) \right)$$

Inputs Instrument

The following tables illustrate examples of inputs instruments including for simple inputs (**Table A3.4**), single-dimension inputs (**Table A3.5**), and multi-dimensional inputs (**Table A3.6**). Note that the names of the inputs are consistent with those in the Q&V instruments. The CBA of the child deworming intervention used a spreadsheet to implement the model. References to underlying data sources are indicated (in square brackets).

Table A3.4. Simple inputs instrument for child deworming intervention

Units			
Number	#		
US Dollars	USD		
Canadian Dollars	CAD		
Percent	%		
Years	Years		
Flag	Flag		
Centimetres	cm		
Key Inputs			
Proportion of medication lost in delivery	10%	%	[1]
Proportion of treatments left incomplete	0%	%	[1]
Discount rate	9%	%	[2]
Simple Inputs			
Average change in MUAC from deworming treatment	0.19	cm	[3]
Healthy growth standards mean MUAC	15.60	cm	[4]
Healthy growth standards standard deviation of MUAC	1.10	cm	[4]
Healthy growth standards standard deviation of height	3.80	cm	[5]
Average change in height from deworming treatment	0.09	cm	[3]
Disability weight used for unspecified anemia	0.004	#	[6]
Disability weight of mild anemia	0.004	#	[6]
Disability weight of moderate anemia	0.05	#	[6]
Relative risk of anemia (U5)	0.93	%	[7]
Relative risk of anemia (5-14)	0.98	%	[8]

Table A3.5. Single-dimension inputs instrument for child deworming intervention

Country- Specific Inputs							
Country			Burundi	DRC	Ethiopia	Malawi	Mali
Median MUAC	cm	[1]	14.00	14.20	12.50	13.20	10.20
Remaining life expectancy (U5)	Years	[2]	66	66	70	67	66
Mean HAZ score	#	[3]	(2.20)	(1.60)	(1.50)	(1.50)	(1.10)
Prevalence of anemia (U5)	%	[4]	58%	65%	52%	55%	79%
Prevalence of anemia (5-14)	%	[5]	40%	45%	32%	46%	67%

References

[1] Regional average was used for Somalia. Median in children without edema was used, as prevalence of edema was very low (1% to 2%) in studied countries. Alvarez, J. L., Dent, N., Browne, L., Myatt, M., & Briend, A. (2018). Mid-Upper Arm Circumference (MUAC) shows strong geographical variations in children with edema: results from 2277 surveys in 55 countries. Archives of public health = Archives belges de sante publique, 76, 58. https://doi.org/10.1186/s13690-018-0290-4

[2] World Health Organization (WHO): Regional Health Observatory - South East Asia. (2019c Life tables by country. World Health Organization (WHO). https://apps.who.int/gho/data/view.searo.LT62000?lang=en

[3] ICF, 2012. The DHS Program STATcompiler: Mean HAZ and WAZ by Country. Funded by USAID. http://www.statcompiler.com. [Accessed March 24th 2023].

Table A3.6. Multiple-dimension inputs instrument for child deworming intervention

Anthropometric Inputs					
Wasting			Mild	Moderate	Severe
Relative risk of mortality	%	[1]	1.77	3.02	5.63
Disability weight	#	[2]	-	0.05	0.13
Stunting			Mild	Moderate	Severe
Relative risk of mortality	%	[3]	1.20	1.60	4.10
Disability weight	#	[2]	-	0.02	0.02

References

[1] See Annex 2.

[2] Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019) Disability Weights. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2020.

The Utility of a CBA Model

Now assume that we have specified all UCBA instruments, including the Q&V instruments of all time series for each of the impacts (Bs, Cs, and Ts), and made all intermediary calculations. The functionality of the CBA is there, but not the utility. To add utility, we return to the investment criteria - in this example, let us focus on the NPV, internal rate of return (IRR), modified internal rate of return, and benefit-cost ratio (BCR) as a measure of whether the benefits exceed the costs for society. One formula is needed:

Table A3.7. Q&V instrument for select investment criteria for child deworming intervention

NPV, IRR, MIRR, BCR			
For NPV, IRR, and MIRR, we use the built-in functions in MS Excel and apply them to the net resource flow (sum of all benefits net of all costs). For NPV and MIRR, we use a 10% discount rate based on the organization's standard. For BCR, we report the ratio of the present value of all benefits to the present value of all costs. The benefits and costs come from related Q&Vs.			
Inputs		**Dimensions**	**Unit**
D	*Discount rate*		%
Final Calculation			

$$NPV^{society} = NPV(D, B1 + B2 + B3 + C1 + C2 + C3)$$
$$IRR^{society} = IRR(B1 + B2 + B3 + C1 + C2 + C3)$$
$$MIRR^{society} = MIRR(D,\ D,\ B1 + B2 + B3 + C1 + C2 + C3)$$
$$BCR^{society} = \frac{NPV(D, B1+B2+B3)}{NPV(D, C1+C2+C3)}$$

Annex 4: UCBA Glossary

Critical Assumptions: The assumptions that matter to decision-makers. These can include the risk and uncertain variables or those parameters that can be controlled by the actors involved (decision parameters).

Decision: A group of actions that come together to achieve an objective: a policy, an investment, or a change in the original path of an operation (such as closure, expansion, regulation, etc.).

Decision Criteria: The outputs of the CBA that can help the decision-making process. These criteria can include common investment criteria such as the net present value (NPV) and the internal rate of return (IRR). However, most CBAs need to report other numerical or visual representations such as the net impact by stakeholder, distributions of net impact over time, or the number of beneficiaries.

Dimension: Classes that add breakdowns to inputs and outputs of a CBA model. Time is the most common dimension in a CBA model. For instance, the real price of a commodity can remain unchanged in the model, therefore it does not have a time dimension. However, if the real price differs for each year, it has a time dimension. Note that applying a trend to a fixed real price within the CBA calculations does not add a dimension to the input parameter. Other dimensions might be based on location, gender, crop, etc.

Impact: A benefit, a cost, or a transfer associated with the decision that is subject to CBA.

Perspective: The view that includes one or more stakeholders or rightsholders in the CBA. A narrow perspective is that of an investor. Most CBAs take the perspective of an economy (country) or the globe (all countries). Stakeholders can be grouped in different ways to form additional perspectives based on geographical boundaries (such as a province), gender, or others.

Q&V: Specifies how an impact, a transfer, a decision criterion, or a timeframe is calculated. The calculation specifies the methodology, inputs, formulation, and the timeframe.

Timeframe: The period in which a calculation is relevant. If a calculation relates to an investment cost, the relevant timeframe can be called the "investment period." The number of timeframes and their complexity changes from one cost-benefit analysis to another. A complex timeframe can have its own calculation.

Transfer: A transaction among the narrow perspectives of a CBA, such as investors and the government, that results in no overall benefit or cost from the economy or global perspective. Examples include taxes and subsidies when the overall perspective is the economy.

Annex 5: Practical Notes

Practical Considerations

1. **How to identify and organize benefits, costs, and transfers in the BC&P instrument?** Benefits, costs, and transfers (flows) can be identified with the notation of B, C, and T, respectively. Flows can be numbered for ease of reference, as in B1, B2, B3, C1, C2, T1, etc. It is suggested to organize flows by type within the BC&P instrument (benefits, then costs, then transfers). Within these, it is suggested to begin by listing the most to least conceptually important (which may or may not ultimately correspond with magnitude).

2. **What is the right level of disaggregation for the BC&P instrument?** The level of disaggregation for benefits, costs, and transfers must be chosen efficiently, balancing between insight provision and ease of communication. The UCBA paradigm recommends an efficient breakdown, such that the impacts instrument requires no more than 15 rows and can fit on a single page. For instance, if operating costs include utilities, stationary, and rent, they can show up each as a separate cost or as a single cost - the operating cost. The decision to keep them separate or aggregate will depend on whether the separation adds any value to the communication of the results. If the disaggregation does not add any value, including the aggregate items is the more efficient approach. Note that the iterative nature of UCBA allows for the introduction of disaggregation later in the process.

3. **Can the subgroups in the BC&P instrument overlap?** UCBA does not prescribe any particular relationship among the perspectives included in an integrated analysis. As a result, perspectives can (but are not required to) overlap with each other. For instance, the economy or country, as a perspective, can be equal to the sum of the other perspectives. However, this relationship is not always an aggregation from left to right. For instance, perspectives based on gender and income group may overlap such that summing them can result in double-counting. Ultimately, the perspectives included must align with the reporting requirements. Therefore, the perspectives captured in BC&P typically undergo revisions when working on the DC&S instrument.

4. **How should practitioners handle the BC&P instrument for final reporting purposes?** A value - such as the present value of the benefit, cost, or transfer - can replace each checkmark in the BC&P instrument for final reporting purposes. The value of the benefit, cost, or transfer may differ for each relevant perspective. Each row will have a corresponding Q&V table, and each checkmark will be a calculation in the corresponding Q&V table. At the reporting stage, the BC&P can also have a

new row at the bottom that shows the net impact from each perspective. This new row will show the sum of the values in each respective column.

5. **How can practitioners ensure that transfers are balanced?** At the reporting stage, if practitioners replace the check marks in BC&P with values: For each transfer, practitioners should cross-check that the horizontal sum across perspectives equals zero (is balanced).

6. **What is the difference between a risk variable and an uncertain variable?** Risk variables are subject to known variability, including the range of possible outcomes and the relative likelihood of their occurrence (e.g., market prices of traded goods). Uncertain variables are subject to unknown variability (e.g., the timing and magnitude of a natural disaster in a particular location) (Kashi & Hyman, 2023). Therefore, the difference between the two is whether their variability is known or unknown.

7. **Should there be a limit to the number of critical assumptions in the DC&S?** Visually, fitting the DC&S instrument (typically structured as a table) to a single page will limit the number of parameters to four or five. The recommendation here is to keep the number of critical assumptions limited. While the analyst can include more, reporting sensitivity analysis for more than five parameters reduces the importance of each to the decision-making process and some will only become a distraction.

8. **What is the distinction between a sensitivity analysis and a scenario analysis?** To distinguish between sensitivity and scenario analysis, a rule of thumb is the number of critical assumptions (and so parameters) involved. If scenarios are only different values for a single assumption, then there is no need to do scenario analysis; it is simply a sensitivity analysis.

9. **When is the best time to complete the DC&S instrument within the model development process?** Using the DC&S instrument, the analyst can obtain feedback from the ultimate users of the analysis at the very early stages about the design decisions that CBA can help inform (design parameters) and main sources of risk and uncertainty. This way, if the ultimate users have questions about the impact of a specific assumption, such as cost or time overrun, the analyst will learn about it before the specification of the calculations. Later, during the analysis or if time brings new evidence and insights, the analyst might identify new critical parameters or decide that some parameters are no longer classified as “critical.” Therefore, this instrument is expected to go through multiple iterations throughout the model development and analysis. Important note: If a critical assumption is found to be of less importance than initially thought, the analyst should document the justification for its removal for future reference.

10. **What if a critical assumption turns out to be an intermediary calculation?** Critical assumptions must be exogenous inputs. Analysts can identify a draft set of critical assumptions at an early stage of a CBA. Since the methodology for calculating each benefit or cost is unclear in the early stages, it is possible for some critical assumptions to end up as intermediary calculations later in the process of developing the methodology. For instance, if the elasticity of demand for a commodity is an exogenous input, the quantity demanded can no longer be among the critical assumptions. If it is, then the price of the commodity and the price elasticity of demand for the commodity must replace quantity as critical assumptions.

11. **Why are there no signs on checkmarks corresponding to transfers within the DC&S instrument?** Within the DC&S instrument, the checkmarks indicate whether a transfer is sensitive to a critical assumption or not. It is not necessary to indicate the direction of the sensitivity, so no sign is required.

12. **Are probability distributions and ranges always needed in the DC&S instrument?** A range of possible values is a necessity for all critical assumptions. Without such a range, having them listed as critical assumptions would be counterintuitive. However, having a Monte Carlo simulation is not always a part of a CBA. Even when Monte Carlo simulations are a part of the CBA, not all critical assumptions would need to be considered a source of variability in probabilistic analysis. A reason for considering a probability distribution as an optional part of this instrument is that design parameters are not a source of risk or variability. Therefore, they do not need a probability distribution.

13. **Are correlations always needed in the DC&S instrument?** No, it is not always necessary to specify correlations within the DC&S instrument. One can only specify a correlation between two sources of vulnerability.

14. **Why does each correlation appear twice in the DC&S instrument?** Correlations create dependencies between the movements of two sources of vulnerability. Both of these variables must be in the DC&S instrument, and the degree of correlation is the same irrespective which end one considers. Therefore, the same correlation would show up once for each risk variable in a DC&S instrument.

15. **How to derive the probability distributions, ranges, and correlations?** Guidance on deriving sensitivity ranges, probability distributions, and correlations is beyond the scope of this article. However, to the degree possible, it is recommended to ensure that the mid-point (within a sensitivity range) and the expected value (within a probability distribution) for a critical assumption are the same as the value used for deterministic analysis (base case).

16. **If an input is introduced in a Q&V, does it need to appear in the following Q&Vs?** Inputs used in multiple Q&Vs must be presented in each of those Q&Vs. An analyst should NOT exclude an input from a Q&V just because it was introduced in an earlier Q&V. A Q&V must remain auditable in isolation.

17. **Can there be multiple Q&V instruments?** There must be a Q&V instrument for each benefit, cost, or transfer identified in the BC&P. Moreover, the Q&V instrument is a meta table, meaning there will be multiple instances of it over the course of the CBA.

18. **Is the Q&V instrument limited to the benefits, costs, and transfers in the BC&P instrument?** The Q&V instrument applies to - but is not limited to - the benefits, costs, and transfers noted in the BC&P instrument. Practitioners may utilize a Q&V instrument to document the approach to calculate decision criteria and for complex timeframes that are dynamically calculated (such as defining the construction period as a function of the start date, expected duration of construction, and the time-overrun as three independent exogenous inputs).

19. **Is there a limit on the length of the Q&V instrument?** It is recommended that a single Q&V instrument, often presented as a table, take at most one page. Q&V instruments can be longer. While having a two-page Q&V instrument remains acceptable, this might be a sign of overcomplication. There are two ways to reduce the size of the Q&V instrument. First, there might be scope to break down the instrument into two or more Q&V instruments. For instance, instead of health benefits, one can define two separate benefits: reduction in premature mortality and reduction in morbidity. Second, some of the calculations may deserve to be independent annexes or research papers that can be then cited in the Q&V. For instance, if a regression is made on primary data to estimate the average wage, the regression analysis and the underlying data do not need to be part of the CBA specification. They can appear as an annex or a separate research paper.

20. **How to break complex formulas?** When a formula is complex and does not fit in a single line, it is useful to add intermediate formulas above the calculation row. For example, quantifying the impact can be a separate intermediary calculation in the Q&V, which is then used in the final formula that values the total impact.

21. **Are there any tips for the mathematical naming of inputs?** Recommended naming conventions include keeping input names as short as possible (one letter where possible), using subscripts (comma separated) to denote dimensions, and using superscripts to concisely add more information to the name (e.g., with (w) and without (w/o) are common superscripts). Similarly, superscripts can be used to distinguish benefit, cost, or transfer flows for a specific perspective (for example, $B1^{Youth}$ from $B1^{Adult}$). Note that superscripts function as part of the variable name, and should not correspond to a dimension.

22. **Where to construct the inputs instrument?** Suppose a spreadsheet is used to implement the CBA model. In this case, it is good practice to set up the inputs instrument (and all component tables) in the same workbook that will operationalize the calculations from Q&V instruments. Doing this will make connecting the calculations tables (implementation of Q&Vs) to the relevant inputs easier. Keeping all Q&V and inputs tables within one workbook is also practical, since a single input may be used in the calculation of multiple Q&V tables.

23. **What is the advantage of using dimensions if a dimension comes with only two or three values (for example, age groups can have two values, children and adults)?** Dimensions can simplify the specification of CBA models. **Table 3.16** shows an example of how the specification of a simple calculation can be shortened using dimensions across the specification instruments.

Checklist

- ❏ Are the flows (Bs, Cs, and Ts) identically listed and named across BC&P, DC&S, and Q&Vs?
- ❏ Are there any inputs in Q&Vs that are missing in the input tables?
- ❏ Are the names of inputs consistent across Q&Vs and input tables?
- ❏ Are the inputs all independent? (Example of dependent inputs: total cost as an input while breakdowns of costs are inputs, too.)