Cost Benefit Analysis: A step-by-step guide to estimating economic impacts

Cost Benefit Analysis (CBA) is as process of analysing as many of the costs and benefits of a projects as is feasible, converting non-market factors where possible to monetary terms. Typical CBA might assess competing projects in terms of the costs and benefits with respect to the return on investment or internal rate of return, calculate the benefit-cost ratio, or employ the net present value model to benchmark projects to determine feasibility - often over a process or product's lifespan. The Benefit-Cost Ratio (BCR) is defined as the net benefits divided by the net costs; as a rule of thumb a BCR greater than two is required for public sector projects, whereas a value greater than 1 is sufficient for private investment decisions. Environmental CBAs are generally thought of as an appraisal of the worth of a project from a social perspective (Bateman, Lovett et al. 2003). They provide information going beyond simple market assessments to a more complete analysis of *value* with the aim of improving decision making, rather than just arbitrating between what might be 'good' or bad' paths to adopt. Whilst there is not a one size fits all model, assessments are increasingly being extended to include sustainability criteria. These involve ranking wider externalities and benefits than cannot be monetised, this can be achieved via surveys or from stakeholder forums.

The factors listed in Figure 1, relate the costs and benefits of the actors involved in a potential soil reconstruction hub where component materials (such as urban green waste and subsoils) can be mixed and stored. The list represents the costs and benefits identified as most relevant by the ReCon Soil partners and stakeholders as a first point of focus related to the recipes and applications deployed in ReCon Soil. As such it is not exhaustive, for example, there may be significant external ecosystem service benefits from the re-use of these materials. The methodology set out here is descriptive and not intended as definitive, as cost and benefit factors will be highly location and project specific It sets out a broad framework approach, based on the ReCon Soil experience, that can be readily adapted for use elsewhere.

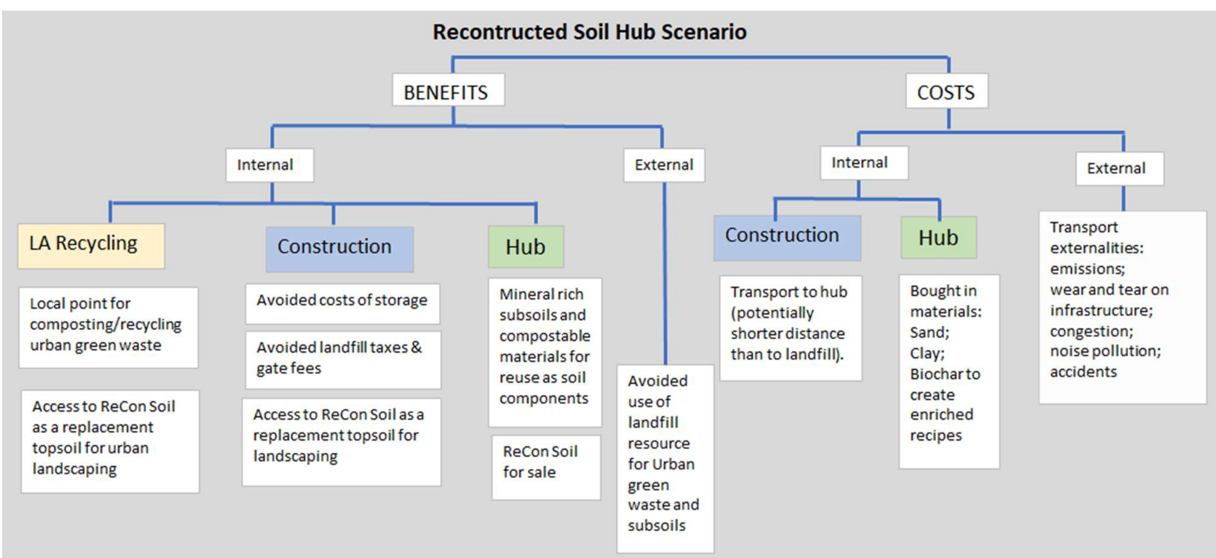

Figure 1. CBA defining costs and benefits to internal and external actors from diverting urban green waste and construction subsoils from landfill for use in creating reconstructed soil. (Framework adapted from Bateman et. al., 2003). LA = Local Authority

Visualising the costs and benefits in this way identifies trade-offs and actors involved. The elements in the 'internal' limb accrue to the Local Authority, Construction, or the Hub itself. Whilst the elements in 'external' limb accrue to society/environment.
It is difficult to identify benefits to society if soil is removed from its natural setting, but the avoidance of disposal to landfill represents an avoided harm, reflected as a societal benefit. Internal costs fall into three categories: landfill taxes and gate fees; the cost of replacement soils; and transport. Externalities (being harms to society/environment) fall into three *damage categories*: human health (mostly from transport); resource depletion (landfill and/or use of virgin material to replace subsoils); ecosystem quality (habitat loss in the soil or from land taken out of use by landfill).

A typical CBA would not distinguish between the actors, simply summing all the costs and benefits and calculating the BCR. However, as many of the externalities accrue to an unspecified body of actors (namely society and the environment), it is difficult to accurately measure these as part of the BCR. One way to evaluate environmental impacts is with the use of Life Cycle Assessments which measure a range of air/water borne emissions and solid outputs from processes.

Reconstructed Soil recipes

Reconstructed soil recipes have been developed by the Reconstructed Soil Project (herein called ReCon Soil). These share basic components such as composted urban green waste and native subsoil or topsoil. Table 1 summarises three recipes by proportional weight. One has been developed in France, two in England; although all can be constructed in either location using locally available materials.

Recipe /component (proportion/t)	**Fr8Ex**	**E1Bc**	**E2Bc**
Excavated subsoil	0.42		0.21
Green waste compost	0.03	0.14	0.12
Composted bark		0.08	
Composted agricultural residue			0.25
Sand		0.35	
Biochar		0.15	0.12
Lignite clay		0.28	
Native component	0.55		0.3
Fr= France; E= England			

Table 1. Proportions of component material used to create FR8Ex, E1Bc and E2Bc soils.

Fr8Ex is a recipe for a soil amendment (not a fully reconstructed soil) designed to improve soil structure and retain nutrients and thus has a prerequisite of native soil to improve. It is likely that the soil product would be suitable for uses such as land reclamation and urban landscaping. Ideally, waste materials (urban green waste compost, excavated subsoil) should be sourced locally to reduce transport emissions. Compost can be produced either by industrial processing (in vessel composting, IVC) or outside via windrow (WR)

E1Bc makes use of composted materials, derived from urban green waste and bark produced on many agricultural sites through normal operations. These soils accommodate inclusion of biochar as a vehicle to sequester carbon long-term.

E2BC incorporates both excavated subsoils and biochar. This recipe combines the reuse of excavated subsoils from construction with otherwise waste outputs from agricultural. These last two recipes have the potential for use as a replacement for topsoil in land reclamation and urban landscaping. As with Fr8Ex, compost from urban green waste can be created either on site or off-site via WR or IVC. The main difference between Fr8Ex and recipes E1Bc and E2Bc is that the latter are fully reconstructed soils which can be made on site or in a soil hub

Steps to draw up a CBA:

To draw up a CBA for a reconstructed soil scenario, the following steps are proposed.

Step 1: Draw up a tree diagram to identify the factors involved in the CBA as shown for example in Figure 1. Ideally there needs to be a base case, or more than one option, for comparison.

Step 2: Convert any qualitative data into quantitative data by attributing monetary values to costs and benefits such as the example given in Table 2. This shows four cost benefit analyses, three for the recipes and one for a base case, such as 'construction'. Although, the monetised values are based on estimated costs and known fees, this is not a clear-cut exercise, there can be many nuances involved in apportioning values (some are described below), and some items may not be easy to value, especially if they were donated in the past or were classified as 'worthless.'

Step 3: Decide how to manage missing elements and any nuances that arise. On some levels estimates are acceptable, although invoices or quotes are more realistic and reliable. In Table 2 estimates of costs are given in ranges and may vary for different units of measurement.

Step 4: Sum the costs and benefits and calculate the BCR as shown in Table 3. The values derived in Table 3 have been calculated using the proportions for the soil recipes given in Table 1 together with the data given in the key. The value for the sale of ReCon Soil is price-matched to the average cost of topsoil, however the quality of the reconstructed soil would be much higher.

Example of nuances:

> For recipe E1Bc, for example, monetisation is a result of situational factors. Clay was a waste from local quarrying activities and obtained free of charge (if sourced directly, clay can be expensive to obtain). Biochar is made from a range of feedstock, and can be refined to different grades, each grade will add to the final cost. Sand is more abundant and relatively cheap in comparison.
>
> For agriculture, traditional methods to abate the effects of soil degradation due to erosion for example, involve the use of inorganic fertilizers and manure. A benefit of ReCon Soil recipe Fr8Ex is that there is an expectation that traditional additives can be replaced or at

least reduced. One way of creating a CBA for this is by apportioning the saving (50% of the cost) to the 'benefits- avoided costs' column, as shown in Table 2. However, if those additives were still required there would be no benefit via an 'avoided cost' route. Similarly, this recipe has been formulated to help retain more moisture, resulting in a reduction in the risk of flooding and erosion Peake, Reid et al. (2014). Monetising this is usually achieved by obtaining historical costs of such events, either through insurance loss or by apportioning the cost of building flood defences. Data on this can be obtained at a regional or national level or from the literature. The data given in the table reflects average direct and indirect costs of erosion and flooding across Europe, as an example, but this would depend on the investment in the level of amendment.

For avoided landfill charges, the monetised entry appears in the benefits column for 'construction' in Table 1, this is because construction is directly benefiting. In a more simplified CBA such as the ones shown in Table 3, it would not matter to whom the benefit accrues and each recipe that re-uses excavated material, (that would otherwise be disposed in landfill) is credited with the avoided cost. In Table 2 an acknowledgement of this appears in the benefits column for the soil recipes that make use of excavated subsoils, but we do not double count the benefit for those recipes in those analyses. The benefit of avoiding virgin aggregate is given as the cost of the aggregate, but this would only apply if the subsoil was regraded/sorted on site and part of the original was used to replace bought in gravel.

For housing construction, land tied up storing subsoils is a cost to the contractor, the value of this would be privately held data, however the cost is likely to exceed the costs of removal, adding to the net benefit for construction, an estimate for residential land has been added to Table 2, the exact value would need to be calculated based on the footprint of the soil stockpile in square meters.

Lastly, there is the distance materials are transported, either to the hub or to a landfill site. The externalities of transport are difficult to allocate, the cost of fuel is only one element.

	Recon Soil Recipe E1Bc		Recon Soil Recipe E2Bc		ReCon Soil Recipe Fr8Ex		Construction Site UK Scenario (t)	
	Benefits (avoided costs)	Costs £	Benefits (avoided costs)	Costs £	Benefits (avoided costs)	Costs £	Benefits (avoided costs)	Costs £
Avoided costs of soil storage on site:								
Land value(residential)/ha							£30k-£200k	
Hub land value (agricultural)		Yes		Yes		Yes		
Gate fees/t			Yes		Yes		£25.00	
Landfill tax topsoil/t (^)			Yes		Yes		£8.17	
Landfill tax subsoil/t			Yes		Yes		£3.25	
Natural resource depletion								
Virgin materials/t		Yes			Yes		£45.00	£30*
Damaged caused by erosion								
Direct/ha					€3.55**			
Flood protection indirect/ha					£137			
Components materials:								
Excavated subsoils	n/a	n/a	landfill	n/a	landfill	n/a	landfill	transport
Native topsoil	n/a	n/a	landfill	n/a	landfill	n/a	landfill	transport
Urban green waste	landfill	on site/local	landfill	on site/local	landfill	on site/local	n/a	n/a
Agricultural residues/bark	landfill	on site local	landfill	on site local			n/a	n/a
Manure					15	15		
Fertilizers					30	30		
Sharpe sand		£40/t	n/a	n/a	30	30	n/a	n/a
Lignite Clay		£700-£1,949/t	n/a	n/a	15	15	n/a	n/a
Biochar		£400 - £4,500/t	n/a	£400 - £4,500/t			n/a	n/a
Subsoil/topsoil transport to landfill		n/a		No		No		No
Subsoil/topsoil transport to hub		n/a		Yes		Yes		Yes
Transport: virgin materials		Yes		Yes		Yes		n/a
Transport externalities		Yes		Yes		Yes		Yes

Notes: 1. (^) Landfill tax for topsoil in UK applies if organic content > 5%. Estimated that max of 8% applies, price per tonne adjusted £102.10*0.08. 2. On site local= local authority waste management stream. 3. Lignite clay prices vary depending on whether it is a waste or a by-product, Imerys, source: sales.marketing@nlcindia.com. 4. Biochar prices vary according to the feedstock, size and quality ranging from £455/t to £5,000/t: price quoted is from Carbon Gold, in Somerset. 5.* anticipated price for ReCon Soil as topsoil replacement. 6. **Patault, Ledun et., al., 2015

Table 2. A monetised listing of the factors in Figure 1.

Recipe /component	Fr8Ex Proportion	FR8Ex Cost WR	FR8Ex Cost IVC	E1Bc Proportion	E1Bc Cost WR	E1Bc Cost IVC	E2Bc Proportion	E2Bc Cost WR	E2Bc Cost IVC
Excavated subsoil	0.42	0	0				0.21	£0.00	£0.00
Green waste compost	0.03	£0.30	£1.47	0.14	£1.40	£6.86	0.12	£1.20	£5.88
Composted bark				0.08	£0.80	£3.92			
Composted agricultural residue							0.25	£2.50	£12.25
Sand				0.35	£14.00	£14.00			
Biochar				0.15	£90.00	£90.00	0.12	£72.00	£72.00
Lignite clay				0.28	£280.00	£280.00			
Native component	0.55	£0.00	£0.00		£0.00	£0.00	0.3	£0.00	£0.00
Total estimated cost /t		£0.30	£1.47		£386.20	£394.78		£75.70	£90.13
Benefits (avoided costs)									
Landfill tax		£1.37	£1.37					£0.05	£0.05
Landfill gate fees		£10.50	£10.50					£5.25	£5.25
Revenue from sale of soil		£35.00	£35.00		£35.00	£35.00		£35.00	£35.00
Total monetised benefits		£46.87	£46.87		£35.00	£35.00		£40.30	£40.30
Benefit-Cost ratio		156.22	31.88		0.09	0.09		0.53	0.45

Table 3. Cost Benefit Analysis for the three ReCon Soil Recipes. Key for underlying costs in Table 3.

IVC= £49/t; WR=£10/t; Biochar £600/t; Lignite clay £1000/t; Sand £40/t; Landfill (inert) £3.25/t

Based on the simplified version of CBA in Table 3, E1Bc and E2Bc would not be viable, a possible variant would be to treat excavated soils as being disposed in sanitary landfill in this way the avoided cost would be higher. The ratio for E2Bc (WR version) would then become 0.82. If the sale price for ReCon Soil increased to £50/t the BCR would just become viable at 1.01. This demonstrates the importance of obtaining realistic estimates for components.

Considering future market conditions, ReCon Soil is a potential direct substitute for multipurpose compost containing peat. As peat is phased out of retail compost (DEFRA 2022), economic theory would suggest that consumers would switch to an alternative of the same quality - ReCon Soil should be well placed to take up this demand, therefore the price would rise.

References

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