iCASP

Integrated Catchment Solutions Programme

Review of Tools

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Executive Summary

Green and Blue Infrastructure (GBI) forms a fundamental part of “place-making” policies and can play a crucial role in the recently declared climate emergency across the United Kingdom. To secure funding, practitioners need to develop an Economic Case that highlights the benefits the GBI investment will generate for society, and in particular that these societal benefits outweigh the societal costs.

A successfully developed GBI business case allows policy makers to address three fundamental questions:

1. Is an individual GBI project or programme value for money?

2. How does the proposed GBI project or programme perform relative to other GBI project and programme designs?

3. How does the value for money of GBI projects relate to other types of (non-GBI) projects?

Practitioners writing business cases for Green and Blue Infrastructure (GBI) have not yet succeeded to apply a consistent approach, and in some cases have been struggling to get their GBI business case approved.

A variety of ‘Tools’ are available to practitioners to facilitate building Business Cases, and in particular Economic Cases for GBI investments. There are two types of Tools that have been applied in the context of GBI business cases.

Tool set 1 is aimed at measuring and quantifying the impacts of GBI projects. Despite the informative outputs generated by this first set of Tools in terms of changes in flows of Ecosystem Services, its outputs are often not in a form that can be readily fed into the Economic Case. Either critical information is missing or conversion factors to translate the identified benefits (or costs) into monetary terms are unavailable.

Tool set 2 combines the measuring and quantification of impacts with conversion factors to express the value of GBI investments in monetary terms. Existing GBI Tool reviews have criticised their compatibility with the notion of welfare economics required to write the Economic Case. These same Tool reviews have highlighted issues with the robustness of the evidence base used to i) measure the impacts of GBI investments and ii) translate these benefits into monetary terms. The critiques encompass the need to use multiple Tools when the project does not fall inside the scope of a given Tool and the risk of double counting benefits.

The current state of play, as reviewed by this document, signifies developments are happening at two fronts. First, high-level guidance for economic appraisal of GBI investments is being put into place by DEFRA through the Enabling Natural Capital Approach (ENCA). ENCA supports the Natural Capital framework to express the impacts of GBI investments in terms of changes in the flows of ecosystem services. Secondly, individual GBI Tools are improving by using more appropriate and up-to-date biophysical models and valuation evidence.

Despite these developments practitioners are expected to judge and justify what “robust” and “appropriate” evidence constitutes. Hence, continued work is required to bridge the gap

between the high-level guidance and the GBI Tools. Two key limitations are highlighted by our review.

On the one hand, there is no consistent approach to quantifying the impact of GBI investments on the flow of Ecosystem Services. That is, the framework is set but more consistency is required in terms of the level of spatial modelling, identification of essential (or minimum set of) ecosystem services that needs to be taken into account for different types of GBI investments, standardisation of units of measurement. In the context of multi-criteria analysis or in the form of the strategic outline case multiple indicators summarising the impact of GBI investments may be useful in reporting the areas in which the project performs well / or less well. However, for developing the economic case we would recommend the development of 'standard' units of measurement.

On the other hand, there is no clear guidance on what constitutes "robust" and "appropriate" valuation evidence to include the measured impact of GBI investments on the flow of Ecosystem Services in the Economic Case. Ideally, this would require additional guidance in relation to the provided valuation reference databases by ENCA or a move to nationally representative values for ecosystem services, as there is for the value of travel time savings and the value of a prevented fatality as presently supported by the Green Book.

In the absence of such clear guidance, we have not identified any single Tool in this review that can meet generally accepted standards of "robustness" and "appropriateness." A Tool is only successful if it meets the expectations of both the practitioner and the evaluator, which at present is not the case for any of the range of Tools that we review. Tools can be beneficial to describe the benefits of GBI investments. Practitioners will, however, first need to set out the key ecosystem services that need to be measured before selecting a specific Tool. Ideally, a single Tool will be informative on the key ecosystem services involved (at the right spatial level). The use of multiple Tools is not recommended to avoid inconsistencies, double counting and misalignment present across different Tools.

Once the changes in the flow of ecosystem services have been quantified the next step is to determine the feasibility of translating these benefits into monetary terms. Instead of using a Tool for this, we would recommend the use of the valuation reference databases listed in ENCA. At present, Tools only offer too limited coverage of monetary values and the evidence used is insufficiently robust outside of the original area of application for which the Tool was designed. On top of that, we recommend that practitioners using the value reference databases listed in ENCA to identify potentially relevant valuation studies and subsequently scrutinise these studies to determine the quality of the source study and thus the valuation evidence. Notably, this requires expert knowledge on the subject.

Considering the above recommendations, the appeal of an 'approved' GBI Tool is apparent as it would create a level-playfield and would significantly lower the resources needed to successfully write the Economic Case. Tools are developed to be pragmatic, cost-effective and easily transferable and accordingly there is a need to find a middle ground. Making progress will inherently be associated with trade-offs and compromises.

The absence of an 'approved' GBI tool lends itself to an alternative solution that GBI investments should not be (or as little as possible) included in the Economic Case. Alternatively, the best place to highlight the benefits of GBI investments is in the Strategic Case. This may have two benefits. Firstly, it allows practitioners to make use of non-monetary measures to quantify the impact of GBI investments. Secondly, by including GBI

benefits in the strategic case, and specifically the strategic outline case, would allow GBI benefits to influence the design of the project at an earlier stage compared to being included only in the Economic Case.

Contents

1. Introduction

The National Planning and Policy Framework defines Green infrastructure as: "*A network of multi-functional greenspace, urban and rural, which is capable of delivering a wide range of environmental and quality of life benefits for local communities*" (Ministry of Housing Communities & Local Government, 2019, p.67). When this concept is extended to include water related elements, the terminology is broadened to Green and Blue Infrastructure (GBI). Where the creation of GBI networks provides significant opportunities for ecological restoration and improvements, the central focus in terms of policy evaluation is the extent to which such networks of natural assets deliver a range of ecosystem services beneficial to society. DEFRA (2020, p.53) acknowledges that "*The amount, quality and location of green (and blue) infrastructure will affect the benefits it provides, as well as who benefits. Good green (and blue) infrastructure can be a significant driver of place-making, economic activity, climate resilience, and health and well-being, in new and existing neighbourhoods and settlements*".

Improving the provisioning of GBI requires policy makers to ensure the necessary funds are secured and to demonstrate that GBI investments are '*value for money*'. Alternatively put, policy makers need to develop a Business Case. Hurst (2019) clearly highlights how each Business Case in the UK is expected to be consistent with the appraisal process as defined by HM Treasury's Green Book (HM Treasury, 2020a). The latter document sets out on how to appraise and evaluate policies, projects and programmes in the UK. The Economic Case forms a central part of each Business Case and summarises the extent to which GBI investments generate benefits to society and particularly whether these societal benefits outweigh the societal costs (both expressed in monetary terms).

The successful development of business cases for GBI allows policy makers to address three fundamental questions. Firstly, is an individual GBI project or programme value for money? As highlighted above, a positive response to this question signifies that the societal benefits of a project will outweigh its societal costs and is thereby worthy to invest in. Secondly, how does the proposed GBI project or programme perform relative to other GBI project and programme designs? Being able to answer this question will help policy makers to identify the projects and programmes that generate the highest value to society. This is particularly relevant as alternative projects and programmes are competing for the same funds and thereby selecting the best project will generate the highest value for money. As such, funds will be allocated efficiently. Thirdly, how does the value for money of GBI projects relate to other types of projects, including conventional grey infrastructure? If a case can be successfully made that GBI projects are providing higher benefits to society than other (e.g. transportation infrastructure) projects, this may help building a case for re-allocating funds to alternative purposes and thereby spur the implementation of GBI projects.

The latest review and update of HM Treasury's Green Book (HM Treasury 2020a, 2020b) highlight that recent appraisal processes have perhaps become over reliant on the outcomes of the Economic Case and have paid insufficient attention to the Strategic Case for implementing projects. This message echoes the outcomes of the related Conceptual Review as part of the present iCASP project on GBI (Pirgmaier and Brown, 2020) and is also engrained in the present document. The Economic Case is, however, still central to policy appraisal practices in the UK. Notably, the same Green Book and its review (HM Treasury 2020a, 2020b) still emphasises its improvements in guidance to translate the benefits (and costs) of environmental impacts into monetary terms. The primary focus of the present document is accordingly on the Economic Case for GBI investments.

1.1 Business cases for GBI projects and programmes in the UK

The Green Book sets out the general framework, principles and guidelines and operates above and across all the different government departments to ensure consistency in the presentation and evaluation of business cases in different application contexts. Individual government departments operate under the umbrella of the Green Book and may provide a more refined and detailed supplementary guidance on how business cases should be developed within their respective application domain. For example, Transport Analysis Guidance (TAG) forms the core reference for building business case in the context of transportation (DfT, 2021). In the context of the environment, DEFRA (2020) recently published Enabling a Natural Capital Approach (ENCA) which aims to support and develop the HM Treasury Green Book principles in relation to natural capital.[1,2]

Building business cases for projects and programmes in the UK follows the Five Case Model (HM Treasury, 2020a). Hurst (2019) provides an insightful summary of the appraisal process and specifically the Five Case Model (p7). Table 1 below provides a short summary of the five cases included in the Five Case Model.

Case	Short description
1. The Strategic Case	The Strategic Case summarises *why* a project is proposed and what it is trying to achieve.
2. The Economic Case	The Economic Case extends the Financial Case by accounting for all the monetary and non-monetary benefits and costs to society. Where possible, it translates these into monetary terms and derives a net present value
3. The Commercial Case	The Commercial Case summarises the options for procurement
4. The Financial Case	The Financial Case summarises the *flow of money*. What are the monetary costs and what are the financial paybacks?
5. The Management Case	The Management Case summarises how the project will be run, including milestones, dependencies and management of risks

With high-level guidance only having recently been put into place, it comes as no surprise that practitioners writing business cases for Green and Blue Infrastructure (GBI) have not been applying a consistent approach, or even worse have been struggling to successfully develop GBI business cases. This challenge particularly refers to developing Step 2 in the Five Case Model, i.e. writing the Economic Case for GBI investments. Unlike the transportation context, where nationally representative values for travel time savings and reliability improvements are available, such nationally representative values are not readily available in the context of GBI impacts and hamper the monetisation of the societal benefits of GBI investments. We take this challenge as the point of departure for the present document.

[1] Earlier references have labelled ENCA as EnviTAG highlighting its correspondence with TAG in the transportation context as supplementary guidance to the Green Book.
[2] At its simplest, a natural capital approach is about thinking of nature as an asset, or set of assets that benefit people (DEFRA, 2020).

1.2 The role of 'Tools' in building business cases for GBI and the emerging challenge

Practitioners make use of, and express a demand for, 'Tools' to write business cases for GBI investments. A variety of 'Tools' is available to practitioners and we can distinguish two types of Tools that have been applied in the context of GBI business cases. The first set of Tools is aimed at *impact assessment*, i.e. measuring the impacts of GBI investments. Generally, this requires users to feed geographical information regarding the application area into the decision support Tool in order to establish the baseline or reference case. On top of that, the proposed changes as a result of the investments are also entered into the decision support Tool to track the changes in, for example natural capital, ecosystem services or other impact metric. In short, these impact assessments Tools primarily make use of *biophysical and/or other non-monetary models* to measure and quantify the impact of GBI investments. Depending on the level of detail and complexity associated with the Tool, users are required to feed in the necessary information using Excel or a more advanced software package.

Despite the insightful outputs generated by impact assessment (or decision support) Tools, insufficient information is often available to practitioners to effectively construct an Economic Case. The key information that is missing is conversion factors to translate the identified benefits (or costs) into monetary terms. The second set of Tools combines the two stages and provides both the impact and the associated impacts on societal welfare expressed in monetary terms. The second set of Tools are at the heart of this report, but discussion will be provided on the first set of Tools where appropriate.

If a "*robust*", easily "*accessible*" and easily "*transferable*" Tool would be available to practitioners, GBI business cases could be written in a consistent and cost-effective way. The majority of impact assessment and valuation Tools are, unfortunately, designed for a specific research context possibly limiting transferability to different application areas. Moreover, the reality anno 2024 is that a plethora of Tools is available to practitioners each associated with its own peculiarities, challenges and shortcomings. Most insightful in this context is the disclaimer of DEFRA in relation to the Tools featured in relation to ENCA:

> *"DEFRA does not endorse how you use these tools. It is your responsibility to assess the appropriateness of the tools you use, and to apply them to appraisal and analysis in a way which is consistent with Green Book and Value Transfer principles. The commentary provided against individual references aims to support this judgement. You must exercise your own judgement about the relevance and robustness of any particular tool, whether or not it is included in ENCA."* (DEFRA 2020a).

This highlights that it is left to the individual practitioner to identify the most appropriate Tool and judge whether the obtained evidence is sufficiently robust. At the same time, the evaluator of the GBI business cases (e.g. the combined authorities) may be of a different opinion and can reject said business case due to the ambiguous definition of which Tools are "*robust*" and "*appropriate*". This is a serious concern and signifies a call for action to address this void.

1.3 The need for compromises

The development of suitable GBI Tools facilitating building Economic Cases for GBI investments across a variety of practitioners and context areas inherently requires a certain degree of *compromise* and trade-off. Developing biophysical, and/or other non-monetary, (henceforth, we refer to 'biophysical models' for brevity) for a given GBI application context from scratch and collecting new valuation evidence alongside is a time-consuming and

resource intensive exercise. GBI Tools thrive on transferring biophysical models (whether they are generic in nature or developed specifically in an alternative location) and valuation evidence (so-called benefits-transfer) from one policy site to another. The more detailed the biophysical models underlying the Tools are in terms of spatial detail and effects accounted for, the higher the resource costs (in terms of expert knowledge, time and monetary costs) of applying the Tools become. This introduces the trade-off between precision and costs. The lower the costs, the more likely the study will be associated with error. Natural England (2013) argues that GBI Tools should therefore only be used to generate 'ball park' figures and that for full scale economic appraisal specific research is required.

An alternative interpretation could be that with the right level of compromise, full scale economic appraisal, i.e. building the Economic Case, is possible. Looking at the broader appraisal guidance in the UK, for certain project impacts nationally representative monetary values are available that can directly be implemented in the economic case despite the acknowledgement that such values might vary due to a variety of reasons. A first example is the value of a prevented fatality (VPF), also known as the value of a statistical life (VSL). The VPF assigns a value to reductions in mortality risk and each expected life saved is currently valued at £2M (HM Treasury 2020a), irrespective of the population to which the risk reductions apply and irrespective of the context in which these risk reductions occur. In the literature, however, there is widespread discussion on whether the VPF (or VSL) should vary by age and or risk context (e.g. Robinson et al. 2021; Dekker et al. 2011). The Department for Transport makes use of the Value of Travel Time Savings (VTTS) to describe the benefits of reduced travel times. A reduced level of segmentation is used in the Department's appraisal guidance TAG (DfT, 2021), whereby the VTTS is allowed to vary by travel purpose (business, commuters and all other non-work trips) and across modes of transport (including car, rail and bus) and distance for business travellers. Similar to the VPF, many factors can be identified that may change the VTTS. For example, travel time saved in congested conditions can be considered more valuable than travel time saved in non-congested travel conditions (e.g. Hess et al. 2017). The choice for working with uniform, or limit variations in, values for project impacts, is somewhat driven by equity consideration, but primarily by pragmatism.

As a result of the compromise that has been made at the level of the policymakers in, for example, the Department for Transport, practitioners are faced with clear guidance. Building a business case in the context of a transportation project involving reductions travel time, mortality risk and even travel time reliability is straightforward relative to building an economic case for GBI. The challenging task of quantifying the impacts of the project on travel demand, and translating these impacts into monetary values is reasonably clear cut since the necessary monetary conversion factors are available to the practitioners in the context of transport appraisal. As mentioned in Section 1.2, that level of compromise, with availability of robust monetary conversion factors, is not available in the context of GBI. One exception is perhaps on the use of values of the amount of carbon sequestered by the project as such values are available in the Green Book (BEIS, 2019).

With respect to the continued development of GBI Tools compromises will not only need to be made at the level of monetary valuation, but also in terms of the impacts being measured (and in which units). ENCA (DEFRA, 2020) is presently making steps on the guidance on impact quantification by supporting the Natural Capital framework and the associated measurement in the change and stock of ecosystem services. The UK Woodland Natural Capital Account (ONS, 2020) highlights that both in terms of quantification and valuation progress is made, but that 90% of the values (being non-market values) are unlikely to be captured yet. Significant

progress is therefore still essential, including the need to identify which effects are essential to include and how these should be monetised.

Where high level guidance is being put into place, individual GBI Tools are also improving in terms of the underlying evidence base on both the impact assessment and valuation. The key gap that emerges here is, however, that these two processes need to be connected for the successful implementation of a pragmatic, robust and transferable Tool which enables writing successful Economic Cases for GBI investments. In our opinion, an open dialogue and an agenda for compromises is the most likely way forward. Notably, this does not imply that a single Tool will be the outcome of this process.

1.4 Who are the relevant stakeholders?

In the described context, several players are operating, all having a clear role to play in moving this agenda forward. Below we identify and briefly provide our perspectives on the role of each player in the described agenda.

1. *Practitioners writing GBI Economic cases.* Interactions with practitioners within the iCASP GBI Business Cases project have revealed that the experienced challenges are rather comparable. Hence, we propose that the barriers experienced (in terms of using the Tool and writing and evaluating the corresponding business case) by these practitioners are identified and collated.

2. *Evaluators of GBI Economic cases.* Combined authorities, local councils have ample experience evaluating GBI Economic cases, but currently lack a consistent framework against which they can be evaluated. Two key tasks are identified here. First, identification of the limitations (but also success factors) of GBI Economic cases that have been evaluated through good and bad practices. Secondly, a perceived set of minimum guidelines for evaluation can be established and contrasted against what is currently included in ENCA.

3. *GBI Tool developers*. The developers of GBI Tools are primarily academics and/or consultants. They have a clear role in improving the existing (and new) Tools and communicating their functionality to their users. Short term progress can be made by addressing some of the short comings in existing Tools as identified by previous reviews (see Section 1.6 and Section 5), including double counting and the use of a more relevant and robust (modelling and valuation) evidence base. Indeed, progress has already been made on these fronts, but challenges remain, including the recognition of the present shortcomings as user guides are not always readily available. In the long term, Tool developers play a central role in addressing the barriers experienced by users and evaluators as identified above, confirming with high level guidance and developing Tools that are “robust”, “appropriate” and “transferable” but still user friendly. We would hint at a preference for fewer rather than more Tools than currently available.

4. *Policy makers*. At the higher level, policy makers can learn from the experiences by the above three players and ultimately decide on appropriate levels of compromise. Hence, we would recommend continuing development of the introduced ENCA framework making use of a dialogue across all identified players. We provide some clear suggestions in the remainder of this document.

1.5 Can a single pragmatic, robust and transferable Tool be found or developed?

Practitioners and evaluators desire having a single GBI Tool at their disposal that takes away their current challenges with writing and evaluating Economic Cases for GBI investments. Whilst ideal from a practical perspective, we recognise that the degree of compromise required to reach the end point of a single tool may be too significant on a variety of fronts.

The conceptual review of the iCASP GBI Business Cases project (Pirgmaier and Brown, 2020) puts forward a number of reasons why building an Economic Case for GBI investments may not be appropriate at all. This would leave us at the complete other end of the spectrum. The solution that emerges under this scenario is that GBI investments should not be (or as little as possible) included in the Economic Case. Instead, the best place to highlight the benefits of GBI investments is in the Strategic Case. This may have two benefits. Firstly, it allows practitioners to make use of non-monetary measures to set out the impact of GBI investments. As such, the first set of Tools identified above will be of significant value (although at present still subject to debate about what is considered as robust and transferable evidence) and alternative evaluation criteria (e.g. multi-criteria analysis) can be used in reaching a decision. Secondly, by including GBI benefits in the Strategic Case, and specifically the Strategic Outline Case, would allow GBI benefits to influence the design of the project at an earlier stage compared to being included only in the Economic Case.[3] This argument is partly recognised by the system-of-systems approach advertised in the supplementary guidance to the Green Book on infrastructure spend (HM Treasury, 2015).

Whilst recognising the importance of the Strategic Case, it seems unlikely that given the current evaluation framework set out by the Green Book, its latest revisions, and further shaped by ENCA that the inclusion of GBI benefits in the Economic Case will not be a requirement. Hence, we foresee a role for expressing GBI benefits (and costs) in non-monetary terms in the Strategic Case alongside the development of a limited set of Tools (for different application context) enabling a robust quantification and monetisation of GBI benefits and thereby their inclusion in the Economic Case.

1.6 The scope, objective and structure of this document

Before continuing, it is important to take stock of the existing set of Tools. In selecting an appropriate Tool, practitioners can make use of three relevant sources.

1. Natural England (NE) conducted a review of Tools and evaluated their adherence to principles of scientific and economic analysis and applicability to the UK (Natural England, 2013). A total of nine Tools were reviewed for this particular study.
2. The Joint Nature Conservation Committee (JNCC) started bringing together different Tools under the name of the Tool Assessor (JNCC, 2016). There is significant overlap in the Tools covered by the two reviews, but the scope of the Tool Assessor is broader than the NE review of Tools because the JNCC review does not necessarily require Tools to conduct the economic analysis. The JNCC review has emerged from a document to an online resource labelled as the Ecosystems Knowledge Network (EKN). EKN's Tools Assessor currently labels seven Tools as suitable for expressing values in monetary terms (https://ecosystemsknowledge.net/tool/monetary).

[3] Hurst (2019) describes the three stages by which projects are short listed. These are the Strategic Outline Case, the Outline Business Case and the Final Business Case. In each of these stages the five-case model as described in section 1.1 is followed. The importance of and the level of detail required for the Economic Case increases towards the full business case, whilst more emphasis is put on the strategic case in the earlier stages.

3. The ENCA framework is accompanied by a set of featured Tools for assessing natural capital and environmental valuation (DEFRA, 2020a). Again, the focus is not entirely on Tools that enable deriving economic valuations of GBI investments. Moreover, the resource does not aim to provide an exhaustive collection of Tools and the overlap with the other two reference documents is noticeable.

The purpose of this document is to i) *synthesise the existing review documents*, ii) *track progress that has been made on specific tools since these reviews have been published*, and finally iii) *identify gaps and ways forward to move towards* the successful creation of robust GBI Economic Cases. The scope of this review is limited to Tools that enable building an economic case and thereby only considers Tools that allow the monetisation of GBI impacts. Note, again, that this does not imply that impact quantification Tools are not essential to understanding the benefits of GBI investments and can be used, for example in the Strategic Case and preparation of the Economic Case.

The document is structured as follows. Section 2 outlines the approach adopted to identify and evaluate relevant Tools to reach our objectives. Section 3 then takes a step back and identifies GBI and its associated benefits. Section 4 covers how the impacts of GBI investment are measured in specific Tools and what limitations there are in this process. Section 5 summarises the valuation approaches used to translate the identified benefits into monetary terms and the challenges practitioners encounter in this process. Section 6 summarises the review of Tools and outlines a roadmap for improvement.

2. Our approach

We started the review process by identifying four sets of Tools:

1. Tools included only in the Natural England (2013) review.
2. Tools included only in the Joint Nature Conservation Committee (JNCC, 2016) and more recent additions to the Ecosystems Knowledge Network (EKN) Tools Assessor
3. Tools included in both the Natural England (2013), the JNCC (2016) review and the EKN Tool Assessor
4. New Tools not included in the above set of reviews

ENCA (DEFRA, 2020a) was published during the writing of this document and was therefore not included in the original review process. Its coverage in terms of Tools allowing the monetary valuation of natural capital investments is similar to the Tools included in the present review. That is, ENCA includes additional Tools, being *Biodiversity Metric*, *Eco-metric*, the *Local Environment and Economic Development Toolkit* and the *Ecosystems Services Transfer Toolkit*, but these do not support the valuation of GBI investments, i.e. building the Economic Case. Thereby these Tools are outside of the scope of the present report. Additionally, the *Environmental Valuation Reference Inventory*, the *Environmental Values Look-up Tool* and the *Woodland Valuation Tool* are supporting the building of the Economic Case, but they only do so by forming a reference database of potential values that can be used once the impact of the GBI investments have been identified through biophysical modelling. As such, they do not reflect an integrated Tool and are also out of scope for the present report. The two remaining Tools referred to and reviewed in ENCA, respectively NEVO and ORVal, are included in our review report.

A full list of Tools covered by this report is included in Table 1 below. We were only able to identify two new Tools supporting the Economic Case that were not included in Natural England (2013) and JNCC (2016) / EKN reviews. These were respectively, NEVO and the Green Streets Valuation Toolkit. Two further references are important to highlight and these are *TAG A3 unit: environmental impact appraisal* and *TAG unit A5.1 Active travel*. These are official documents developed by the Department for Transport that are aligned with the welfare economic principles set out in the Green Book. Most notably, they can be considered as robust sources of evidence and can therefore support the Economic Case for GBI investments, especially in relation to benefits arising due to (increased) active travel (DfT 2021b, TAG A5.1) and noise, air pollution and greenhouse gasses (DFT 2021a, TAG A3).

For the Tools in sets 1-3 (including NEVO), we examined the original review reports and identified whether updates have been implemented and to what extent these updates have overcome the original concerns. For the Tools in set 4, we have conducted new reviews. The individual review documents complement the existing individual reviews and are available upon request.

Table 1: Overview of Tools included in various reviews

Tool	Natural England (2013)	JNCC (2016) & EKN (2021)	iCASP (2021)
GI-Val	Yes	Yes*	Yes
i-Tree Eco	Yes	Yes*	Yes
InVEST	Yes	Yes*	Yes
CAVAT	Yes	No	Yes
Helliwell	Yes	No	Yes
CNT. Guide to valuing Green Infrastructure from the Centre for Neighbourhood Technology Chicago (US)	Yes	No	Yes
Health Economic Assesssment Tool (HEAT)	Yes	No	Yes
ORVAL	No	Yes*	Yes
CIRIA B£ST	No	Yes*	Yes
Natural Capital Planning Toolkit	No	Yes	Yes
Co$ting Nature	No	Yes*	Yes
EcoServ-GIS	No	Yes	Yes
Participatory GIS tool	No	Yes	Yes
SENCE	No	Yes	Yes
TESSA	No	Yes	Yes
Viridian	No	Yes	Yes
LUCI	Discarded	Yes, not on EKN Tool Assessor in March 2020	Yes
ARIES	Discarded	Yes	Yes
Pollution Removal by Vegetation		New on EKN Tool Assessor in March 2020	Yes
NEVO		Yes*	Yes
Green Streets Valuation Toolkit			Yes
TAG A3 unit: environmental impact appraisal			Yes
TAG A5.1 Active travel			Yes

* Identified by a revision of the EKN in 2021 as a Tool suitable for monetary valuation

3. Defining GBI and its associated benefits

Before moving into a discussion of the various Tools and their updates, this section provides a better understanding on what the notion of GBI entails. A good point of departure is the UK Green Building Council report from 2015 aimed at demystifying green infrastructure (UK GBC, 2015). Following their definition, which is largely consistent with the one provided in Section 1 by the Ministry of Housing Communities & Local Government, Green and Blue Infrastructure (GBI) represents:

> "*A network of green (soil covered or vegetated) and blue (water covered) natural and semi-natural features within and between our villages, towns and cities that maintain and enhance ecosystem services*".

The above definition. GBI takes various scales and can range from individual buildings, streets, to parks, wetlands and forests. By now it is widely acknowledged that GBI provides a vital role in adapting to climate change, maintaining and improving biodiversity and human health and well-being. The multi-dimensional and multi-functional nature of GBI makes it an attractive, but also a challenging topic.

The societal benefits generated by GBI are typically referred to as Ecosystem Services. Ecosystem services play a central role in the notion of Natural Capital underlying the ENCA framework (DEFRA, 2020). Natural Capital refers to the stock of '*natural assets*' (e.g. forests, rivers, biodiversity and minerals). From this stock of natural assets ecosystem services flow, which either directly or indirectly through some form of human intervention, capital or management generate societal benefits and hence have a value. The role of stocks is important in this context, because the size of available natural capital may affect the extent to which they are able to provide our much-valued ecosystem services. In academic terms, non-linearity and interaction effects are central to the notions of natural capital and ecosystem services. It is the complex nature of these two entities that makes measuring impact and translating the impact of GBI investments into monetary terms a challenging task.

The UK National Ecosystem Assessment (UK NEA, 2011) report classify four different types of ecosystem services:

1. *Provisioning services* – comprising resources that can be directly harvested from the ecosystem, including food, timber and other materials
2. *Regulating services* – comprises the impact of the ecosystem on local air quality, water management and climate
3. *Supporting services* – comprises the role the ecosystem plays in supporting other ecosystem services, such as pollination and soil formation
4. *Cultural services* – comprises the non-material benefits people experience from ecosystems, such as recreation and aesthetics.

Ultimately, quantifying the impacts of GBI investments on the flow of ecosystem services – likely through the change in natural capital - is not an easy task and requires a thorough understanding on the natural processes that govern the flow of these ecosystem services. For example, if the proposed GBI investment (e.g. a given type of trees) is not fit-for-purpose, the GBI investments may not be effective or even undesirable if it disturbs the balance of the considered ecosystem.

4. Measuring the impact of GBI investments

In an ideal world, any form of impact assessment (or cost-benefit analysis) positions the impact of GBI investments (the "*Do-something*" scenario) against the current state of play (i.e. the "*Do nothing*" scenario). The former requires consideration of current (and future) stocks of natural capital and associated flows in ecosystem services. The latter would require quantifying the respective changes in these elements.

It comes as no surprise that quantifying and measuring current, future (and changes) in stocks of natural capital and flows in ecosystem services is not a trivial exercise. The complex nature of ecosystems is recognised by most Tools. In general, they rely on robust scientific models describing how the properties of the considered ecosystem translate into ecosystem services. Assessing the quality and robustness of the referred models is not the focus of this report. However, we do wish to highlight that the Natural England (2013) review had indicated in Appendix A.2.4 (p.36) that: "*the scientific assumptions applied in many tools may be refined as new data becomes available and the evidence base expands through case studies and practical experience in using the tools*".

Based on the updates made to the different Tools, including i-Tree which was criticised by Natural England (2013) for relying on a US evidence base, progress can be observed as the evidence base is indeed improving (both in terms of models and valuation). That does not mean that the issues are fully addressed. Below we highlight three factors that should be at the heart of the discussion on how Tools should be improved to support the building of Economic Cases for GBI investments. This specifically relates to the notions of geographical scale, ecosystem services and units of measurement. As pointed out above, Tools are developed to be pragmatic and cost-effective solutions and hence a certain degree of compromise is required in this debate.

Our observations are as follows:

- Different Tools operate at different **geographical scales** (e.g. local, regional, landscape and national). The more localised the biophysical model, typically the more contextualised the required inputs are. This highlights an important trade-off between the extent to which a Tool can account for local properties and the amount of input information required. As such, scale has a large influence on the quality of the baseline data and the ability of the Tool to predict impact and effects of GBI investments. Moreover, more detailed Tools, like ARIES, require highly skilled users to operate the Tool. This enables catchment scale evaluation. It is this specificity that, however, prevents easy uptake of the Tool and generalisation of its results.

- Different Tools measure different types of **ecosystem services**. Table 2 in the Natural England (2013) review is illustrative for the diverse coverage of the different Tools. Some Tools are highly specialised (e.g. i-Tree) whereas other Tools have a broader coverage of ecosystem services (e.g. InVEST). Often the set of ecosystem services covered is linked to the original application for which the Tool was designed. The consequence is that when one wishes to quantify ecosystem services that are not covered by the Tool, another Tool needs to be used which is not necessarily consistent. This introduces the risk of double counting of benefits and reducing the robustness of the Business Case in general as benefits are not necessarily additive. This issue was already recognised by the Natural England (2013) review.

The **units of measurement** by which ecosystem services or natural capital are measured are not consistent across Tools. This complicates the comparison and validation of different Tools against each other. More importantly, this leaves the practitioner wondering what the correct unit of measurement is. Drawing parallels with the transportation literature where minutes of travel time saved are a common unit of measurement of benefit it appears that such common classifications are not present.

We observe an increasing tendency to translate impacts into indicators or indices. For example, the Natural Capital Planning Tool translates the impact of GBI investments on different Ecosystem Services in the form of impact scores (ranging from -5 to 5). Indeed, such indicators and indices may provide policy makers with useful and interpretable information on how their investments perform on different components. Unfortunately, such indicators are not applicable in the context of building an Economic Case. Namely, an improvement from 0 to 1 in the NCPT Tool is not a useful measure due to the implemented normalisations to reach the respective -5 to +5 scale. Similar challenges of implementing such indicators in cost-benefit analysis have been experienced in the context of the Pedestrian Environment Review System (PERS) by Transport for London which scores pedestrian environments on a scale of -3 to +3. We return to this issue in the section on valuation.

- A key set of principles underlying the Green Book are those of **proportionality and scalability**. That is, ideally the methods are 'easily' applicable and amenable to a wide range of projects and programmes of various sizes and contexts (see also TAG: advice for the technical project manager, DfT 2018). However, this appears to be particularly challenging in the context of natural capital and ecosystem services due to the high degree of contextual effects present. That is, planting a single tree of the wrong sort may have little impact, but a different tree, larger number of trees or a network of small projects may substantially increase the benefits of a single project.

The previous Tool reviews have identified limitations in the existing biophysical modelling approaches. Several Tools have been updated and either acknowledge those limitations or have improved upon them. A clear area where improvement can be made is for individual Tools to provide a clearer version history alongside a record of improvements made. Easier access to the user guides which explicitly recognise the purposes, workings and limitations of the Tools would be also highly recommendable.

Despite these improvements this section has highlighted that at present there is an insufficiently clear end point as to what an ideal GBI Tool should measure (i.e. which ecosystem services), at which scale these should be measured and by which units. Such a GBI Tool should not be all encompassing and overly complex, but instead should reflect the notion of proportionality and scalability whilst satisfying the need of practitioners to effectively illustrate the benefits of their respective project and of project evaluators to see the required evidence to support such a project.

5. Valuing the impact of GBI investments

The previous section highlighted that consistently measuring the impact of GBI investments on Ecosystem Services and Natural Capital in a pragmatic way is a challenge of its own. The next challenge that emerges is the connection of the measured impacts (i.e. the benefits) to corresponding monetary valuation evidence allowing the translation into monetary benefits.

It is important to note the distinction between the Economic Case and the Financial Case. In the Economic Case the focus is not on how the *money* flows and what the return of investment will be for stakeholders. Instead, it is aimed at quantifying the welfare implications for society as a whole and this process requires aggregating the monetary and non-monetary cost and benefits to society. The majority of benefits from GBI investments take the form of non-monetary benefits as there are no direct markets on which ecosystem services can be traded. Non-market valuation methods allow the translation of improved or additional ecosystem service flows into monetary terms (Ozdemirogclu et al. 2016).

ENCA refers the practitioner to several reference databases, including the Environmental Valuation Reference Inventory, the Environmental Values Look-up Tool and the Woodland Valuation Tool. This already highlights that most Economic Cases rely on valuation evidence based on the so-called '*benefit transfer*' method. That is, valuation evidence obtained in one place is geographically transferred to another location (most often without correction for local factors). An example might be use of hedonic property pricing study for air quality valuation conducted in a certain area (e.g. a high value property area), which is subsequently being used in a different area (e.g. a low value property area). The challenges associated with such value transfers should come as no surprise.

The benefit of these reference databases is that practitioners, in theory, can make use of the *most appropriate and up-to-date* valuation evidence base. However, this does not come without its challenges. An examination of these reference databases reveals that:

- Most valuation evidence is based on the Stated Preference methodology and opportunity costs. Revealed Preference evidence is only available to a limited extent. This implies that most evidence is based on respondent behaviour stated in hypothetical surveys instead of real world markets. The validity of individual value estimates can therefore be questionable and practitioners would need to examine the original study to determine the quality of the selected value estimate.

- Most valuation evidence is obtained in a very localised and contextual setting using a relatively small-scale evidence base (e.g. limited number of observations). This specificity limits the extent to which the value estimates to a different geographical or socio-economic context.

- The units of measurement vary significantly across valuation studies; hence the chances are small that obtained measures of impact on ecosystem services matches up with valuation evidence available in the reference data sources.

- There is significant variability in the available valuation evidence base. That is, value estimates for the same type of benefit may vary by a substantial factor across different valuation studies. Partly this is the result of varying definitions used in the studies (introducing the risk of double counting), but also varying quality in the design and analysis of the valuation study. Without examination the original source studies it is therefore very hard to confidently select an appropriate value if available.

The developers of Tools are faced with the same challenges when connecting the outputs of the biophysical models with valuation evidence to present the benefits into monetary terms. As highlighted by Natural England (2013), Tools like CAVAT make use of the costs of planting and maintaining a tree, but do not measure its value. Hence, the Tool is not suitable for the purpose of cost-benefit analysis and not in line with the principles of welfare economics as set out in the Green Book (HM Treasury, 2020a). Together with the disclaimer made by ENCA (see introduction section), it becomes very clear that the onus of responsibility to use "robust"

and “appropriate” valuation evidence is put on practitioners. As a result, they are expected to be experts both on understanding the impact on the biophysical side as well as the economic side.

It seems unrealistic to assume that, for example, a local civil servant is able to: i) evaluate the quality of the underlying evidence base by using the latest guidelines for Stated Preference Studies (Johnston et al. 2017), ii) judge whether the available evidence is transferable to the considered application context (e.g. Johnston et al. 2015), iii) judge whether the valuation evidence aligns with the evidence base of the case study in terms of double counting, additivity and missing values (e.g. ORVal only captures recreation values).

Despite having access to increasingly relevant valuation evidence, which has helped Tools like i-Tree to improve, there is still a significant gap that needs addressing. Again, it is helpful to look beyond appraisal for GBI to develop a perspective to how this gap can be addressed. We have already referred to existing national guidance on valuing changes in travel time savings by the Department for Transport. To develop those values a nationwide Stated Preference study was conducted where ultimately nationally representative values were developed for a limited number of traveller segments (see Batley et al. 2019). In similar vein, to quantify the health benefits of reductions in air pollution, the UK relies on the concept of a value of a life year (VOLY), which is based on, again, a nationally representative contingent valuation study (Chilton et al. 2004). Moreover, these values and studies have been extensively scrutinized before they have been recommended for official use in government policies.

The state of play in the context of GBI investments is completely different, where the current guidance is to: i) select the most appropriate value available, and ii) for both the developer and evaluator of the Economic Case to form a judgement about the robustness and appropriateness of these values. There is a clear role for central government to move towards a set of nationally representative values for given units of ecosystem services. Moving towards nationally representative values inevitably comes with trade-offs and compromises, because a unit of a given ecosystem service improvement is unlikely to be the same elsewhere (just like the reductions in mortality risk vary across age and health group; and travel time savings vary by travel characteristics such as travel mode and purpose). A nationally representative value does show a certain degree of pragmatism and consistency and is in our view the missing link between the high-level guidelines laid out in ENCA and their implementation in GBI Tools.

The recent review of the Green Book (HM Treasury, 2020b) signals developments are likely to happen in two areas. Firstly, it highlights that in recent years perhaps too much emphasis has been put on the outcome of the Economic Case, i.e. the Benefit-Cost Ratio. The inherent complexity of putting a value on nature, natural capital and ecosystem services has led to many environmental benefits (and costs) not being monetised. This has not helped the appraisal of GBI projects and it is therefore recommended by the Green Book Review that more emphasis should be put on the Strategic Case instead of the Economics Case. This first development would reduce the burden of monetising changes in natural capital and flows of ecosystem services and only require a more general assessment on the importance of GBI impacts for which impact assessment Tools can be very informative. The second area of development is aimed at still monetising impacts where possible. At this stage it is, however, unclear whether this will take the form of value reference databases or nationally representative and robust valuation evidence.

6. Conclusions

There is increasing demand for Tools by policymakers and project managers to assist in the writing of the Economic Case for GBI investments. The developments in this context are impressive as illustrated by: i) the variety of different tools that have been developed (focused on measuring impact only, and measuring and valuing impact), ii) the number of reference inventories practitioners can explore to identify relevant valuation evidence to be used in the economics case and iii) the introduction of ENCA as high-level policy guidance to supplement the Green Book.

In the context of previous reviews of Tools, we have observed that the existing Tools are improving by introducing more appropriate and context specific evidence (both biophysical and values). As such, the Tools represent the best-practice and the most feasible and cost-effective alternative to fit-for-purpose impact and valuation studies. Structural changes to these Tools have, however, not been observed and hence some of the key limitations persist. We interpret this as a continuing development where different actors (practitioners, evaluators, tool developers and national policy makers) each have a role to play to the state-of-practice forward.

Compared to the transportation literature, similar developments and challenges are and have been experienced in expanding transport infrastructure appraisal beyond time savings. For example, improvements to the Urban Realm face similar challenges of quantifying the benefits of improved placemaking policies and expressing their values in the form of, for example, ecosystem services. However, the transportation sector is managing to gradually increase the scope of the Economic Case over time, by accounting, for example, for the impact of reliability, and crowding impacts in public transport. Current developments investigate whether time savings vary in value between free flow and congested time (WSP,2018). This circumstantial evidence highlights that a feasible end point of usable tools that align with high-level appraisal guidance arise through step-by-step improvements.

The key words that should inform this improvement process are ‘compromise’ and ‘trade-offs’. For tools to be pragmatic, appropriate, robust and cost-effective compromises need to be made in terms of the level of geographical detail and the accounting for the number of ecosystem services and their interactions. Subsequently, there is a need for consistent units of measurement to quantify the improvements in ecosystem services and a need to associate these units of measurements with robust valuation evidence. In our view, the key player in this context is DEFRA which could supplement ENCA with more detailed guidance for practitioners.

In absence of this guidance, we have seen an increasing emergence of different Tools each with their unique features and limitations. Unfortunately, as a practitioner the use of a specific Tool will not guarantee that the evaluator will consider its use as robust evidence, particularly in the context of the Economic Case. As a result, we are not recommending the use of any of the Tools included in this review. Namely, a Tool is only successful if it meets the expectations of both the practitioner and the evaluator, which at present is not the case, and facilitates the writing of the Economic Case. What is clear at this stage is that ENCA supports use of the natural capital framework to quantify the benefits of GBI investments. As such, there is a need to measure the change in the flow of ecosystem services. Various Tools can be beneficial in this process, but practitioners will need to first set out the key ecosystem services that need to be measured before selecting a specific Tool. Ideally, a single Tool will be informative on the key ecosystem services involved (at the right spatial level). The use of multiple Tools is

not recommended in order to avoid inconsistencies, double counting and misalignment across different Tools.

Once the changes in the flow of ecosystem services have been quantified the next step is to determine the feasibility of translating these benefits into monetary terms. Instead of using a Tool for this, we would recommend the use of the valuation reference databases listed in ENCA. At present, Tools only offer a too limited coverage of monetary values and the evidence used in insufficiently robust outside of the original area of application for which the Tool was designed. On top of that, we recommend that practitioners using the value reference databases listed in ENCA identify potentially relevant valuation studies and subsequently scrutinise these studies to determine the quality of the source study and thus the valuation evidence. Notably, this requires expert knowledge on the subject.

Considering the above recommendations, the appeal of an 'approved' GBI Tool is apparent as it would create a level-playfield and would significantly lower the resources needed to successfully write the Economic Case. At present, the availability of an 'approved' GBI Tool is, however, a utopia. The ultimate question is whether such an 'approved' Tool is feasible? The answer to that question depends on the amount of compromise and trade-offs that practitioners and evaluators are willing to make.

In our opinion, developments in that direction can take place in two separate pathways. Firstly, the impact assessment part of the Tool(s) can be continuously improved and successfully feed into the Strategic Case and thereby already influence the decision-making process from an early stage without the need for monetary valuation. Secondly, the monetary valuation component can be progressed, and our recommendation would be to move from value reference databases to nationally representative values for given ecosystem services. Ultimately, these two strands of work would need to be aligned to complete the circle. Inevitably, the necessary path of compromise and trade-off will be subject to criticism. Particularly obtaining nationally representative valuation evidence may be criticised due: to i) the complex dynamic and multifaceted nature of ecosystems and natural capital and ii) the hypothetical nature of Stated Preference studies which are most likely to be used for these purposes.

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