Institute and Faculty of Actuaries

Green Book reform

An actuarial perspective on transformational change and the Green Book discount rate

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Key findings and recommendations

At present there is a risk that viable UK transformational - and other long-term - projects do not progress. This is both due to technicalities in the Green Book discount rate guidance and an over-reliance on numerical results, in the form of cost benefit analysis, when appraising projects.

Key findings

Actuarial standards would require regular review of valuation methodologies, including discount rates, and the approach taken in this paper has been to carry out an actuarial review of the discount rate underpinning the Green Book appraisal process. This review shows that:

- Despite positive progress being made since the last Green Book review in 2020, challenges remain when applying the Green Book's current methodology to transformational projects. This continues to leave them at risk of undervaluation.

  One important example is the high level of uncertainty present in transformational projects. Unlike risk, uncertainty by its nature defies quantitative assessment such as cost benefit analysis. This is of particular concern given users of the Green Book still often place a significant over-reliance on cost benefit analysis results relative to other assessments required by the five-case model.

- The current Green Book discount rate, the Social Time Preference Rate (STPR) uses historic data to underpin both the wealth effect and the declining rate schedule. It also applies the same discount rate to transformational projects as those which elicit marginal change, despite their fundamentally different nature and impact. In relation to the STPR and its components:

  - The wealth effect is proportional to an assumed 'best estimate' increase in real per-capita consumption growth over the medium to long term, with the current assumption based on data from 1949-1998. We believe this analysis may now overestimate the likely 'best estimate' rate for future growth.

    In addition, increased uncertainty and the skewed nature of the outcomes distribution means there is now a very real plausibility of far lower growth outcomes than previously assumed, potentially exposing future generations to a far greater burden of costs than those faced by current generations.

  - The STPR rate declines over time, with the speed of decline, and the rate floor it tends toward, based on US academic research undertaken in 2001. However, as with the wealth effect, that work assumed that future uncertainty would mirror past uncertainty, a conclusion which we believe is highly unlikely to still be valid today, particularly in light of climate change uncertainty and its implications.

  - The pure time preference represents society's preference for consumption now rather than in future and is often the subject of debate in an intergenerational fairness context. We believe this debate is particularly relevant to transformational projects which are seeking to make changes to the present system which will impact future generations more than our own.

Our analysis of two different Environment Agency funded projects showed materially different Benefit Cost Ratio (BCR) outcomes when the valuation methodology was updated in a way we believe may be more appropriate for modern circumstances. This includes up to a 20% increase in BCR if the

headline discount rate is reduced by 1%. Projects with longer time horizons were far more sensitive to changes in both the headline and declining rate, emphasising the risk of their undervaluation when adopting current approaches.

Recommendations for HM Treasury

Our full recommendations are set out in section 6, and include the following.

In relation to the discount rate used to appraise projects:

1. **For all projects** reconsider the headline wealth effect as well as the declining discount rate schedule (both time-steps of decline and / or to the rate of decline at each time-step) to account for greater uncertainty in possible future growth rates, and the possibility of much lower growth rates than previously anticipated.

2. **For all projects** consider applying a sensitivity removing the wealth effect from appraisal calculations. This would ensure that decision makers for all projects understand how BCRs would be impacted if future growth in wealth is much lower than the central assumption assumes.

3. **For transformational projects** consider removing the social time preference rate from baseline calculations, or, as a less preferred option, introduce its removal as a sensitivity calculation.

4. **Enhance the evidence base for discounting impacts** by requiring users of the Green Book to calculate the duration of annual costs and benefits respectively for their projects and use this to assess and monitor any bias toward short termism on an ongoing basis. (See Appendix B for a definition and example calculation of duration.)

5. **Undertake additional research to assess intergenerational fairness implications of the Green Book discounting approach** including setting HM Government's intergenerational risk appetite and exploring potential technical mechanisms to improve intergenerational fairness.

In relation to the wider appraisal of transformational change:

6. **Carve out what counts as transformational**, using a top-down approach by defining key systems changes required and their implications, and setting out concrete examples to guide users.

7. **Reduce reliance on quantitative measures when appraising transformational projects,** providing clear guidance that, due to inherent uncertainties, the economic case, including cost benefit analysis, should form a smaller proportion of the decision making criteria than for non transformational projects.

8. **Embed assessment of co-benefits for all transformational projects** via a succinct principles based framework. A useful starting point for this framework could be the 'Triple Dividend of Resilience' approach used to assess climate adaptation projects in Defra's supplementary accounting for climate change guidance.

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Section 1: Introduction

Purpose and scope

The purpose of this paper is to provide an actuarial perspective to support HM Treasury with the 2nd finding and action from the 2025 Green Book review published here. That action is to undertake an assessment of the discount rate underpinning transformational change to ensure it is taking a fair view of the long-term benefits that arise from transformational investments.

Whilst the focus of HM Treasury's review is the discount rate, calculations which use discounting are embedded into the wider Green Book appraisal process. Therefore we cannot consider the use of discount rates in isolation and must instead take a holistic view of both discounting itself and the appraisal system in which it operates.

As such, whilst commentary focuses on the choice of discount rate, we have also included supplementary recommendations which we believe have the potential to enhance the appraisal of transformational projects as the Green Book continues to evolve over the longer term.

In preparing our paper we have undertaken research which has included discussions with:

- the HM Treasury Green Book team (to better understand current challenges and the scope of HM Treasury's review) and
- the Environment Agency (to better understand practical challenges they - and other public bodies - face when using discounting in the appraisal of their projects and portfolios).

Practical interpretation of guidance

We consider that the way in which the Green Book drives better societal outcomes is not based solely on the theoretical correctness of its framework, but instead also inextricably linked to its practical application by public bodies. Inconsistencies in how the Green Book is applied may naturally lead to inconsistencies in which projects are funded; particularly for areas of high uncertainty with greater risk of estimation error, subjectivity and bias.

Therefore, we believe consideration of both the conceptual framework of the Green Book and it's practical application is important for this review. We thank the Environment Agency for the provision of two case studies to support our analysis; however, we also note that there may be a wider variation in the practical application of Green Book guidance across government than we have had access to.

Balancing technocratic and political considerations

During a time of heightened geopolitical risk, it is topical to also consider the application of the Green Book in a political context. In so far as is possible, we believe the Green Book should be established upon sound economic and financial principles, some of which we examine within this document.

Accordingly, when we comment on factors relevant to the discount rate, our aim is to improve the existing evidence base for setting such a technocratic discount rate. Hence our commentary introduces and explores the implications of concepts such as increased climate uncertainty, and the skewed nature of the outcomes distribution, neither of which are currently allowed for in the discount rate setting approach.

However, we are also of the opinion that in practice, as a vehicle for the investment of public funds for the benefit of society, the Green Book cannot operate in a purely apolitical context and cannot be static to societal changes and obligations. This is reflected in aspects of our commentary, such as our recommendation for HM Government to set an intergenerational fairness risk appetite.

Overall we believe that when reviewing the Green Book and its discount rate, ensuring an appropriate balance between technocratic and political considerations will be essential to ensure cost effective, responsible and transparent use of public funds.

About the authors

The authors of this paper comprise six members of the actuarial profession, who belong to a Task and Finish Group set up by the Institute and Faculty of Actuaries (IFoA) Sustainability Board.

The IFoA represents and regulates over 34,000 members of the actuarial profession worldwide. The IFoA's Sustainability Board comprises senior members of the profession and carries out thought leadership work to promote understanding of risks relating to climate change and the environment, often with a public interest agenda.

Actuaries are known as problem solvers and strategic thinkers who use their actuarial skills to help measure the risk and impact of future events. They are well versed in dealing with risk and uncertainty, and are able to understand and communicate complex technical concepts clearly.

The actuarial profession, working across the fields of insurance, investments and pensions, deploys statistical techniques and analysis in the assessment of risk, opportunity and equity over long-term horizons; transformational change within a climate change context requires consideration of similar long-term inertial factors.

We are grateful to Mark Freeman (University of York) and Ben Groom (University of Exeter) for their academic review of our paper. We also thank Sandy Trust, alongside our second anonymous reviewer, for their actuarial peer reviews.

Section 2: Understanding transformational change

Transformational change refers to large scale, system-wide shifts which can involve irreversible or long-term structural change. Examples of this in a sustainability context could include reforming the national energy grid, or investment allowing widespread implementation of electric vehicles.

On the other hand, marginal change refers to incremental adjustments within existing systems, such as renovating a public building, or adding a lane to an existing road. When referring to transformational projects within this paper, we are referring to projects which feed into system transformation, and so should not be considered in isolation in the same way in which projects leading to marginal change would be.

Why transformational change is important - value beyond specific project

Without a systematic lens, there is a risk of funding projects that make sense in isolation but undermine or delay long-term transition goals. The use of marginal project appraisal methods can overlook positive externalities created by systematic change - for example innovation spillovers, behaviour shifts and reduced pollution contributing to better air quality and biodiversity. System-level projects can multiply the impact of individual projects, especially if they align with strategic objectives such as the Net Zero target. The Green Book specifies that projects should align with strategic objectives, and so projects should be assessed as part of a systematic change rather than individually.

Uncertainty and evaluation of transformational systems

In understanding transformational systems, 'uncertainty' should be considered as distinct from 'risk', following the conceptualisation of the concepts by economist Frank Knight in the 1920s. 'Uncertainty' relates to the lack of any quantifiable knowledge about some occurrence, as opposed to 'risk' which is quantifiable in statistical terms. Some key differences between risk and uncertainty are summarised in the graphic below:

Risk	Comparison Basis	Uncertainty
An event, if occurs, can affect any project objective	**Definition**	There is no information about the future event, or impact
Can be measured	**Key Features**	Cannot be measured
Outcomes are known; risk can be controlled	**Control**	Outcomes are unknown, uncertainty cannot be controlled
Have the probability of occurring	**Probability**	Probabilities of uncertainties cannot be guessed

Figure 1 - Comparison between risk and uncertainty

While the original conceptualisation of 'Knightian' uncertainty may be interpreted as binary (i.e. a risk is either known or unknowable), practically we consider a spectrum to exist between quantifiable risk and uncertainty.

High uncertainty presents a challenge in many quantitative evaluation systems as there is, by nature, limited data or reference points from which to base any evaluation. EEIST (The Economics of Energy Innovation and System Transition, a University of Exeter led project) acknowledge this in their report:

> *"Adding up costs and benefits presumes they are reasonably predictable and quantifiable with some confidence. But many of the most important benefits of a low-carbon transition... are not knowable with confidence. Omitting these elements from the calculation creates a bias towards inaction."*

Why ‘uncertain’ transformational systems are a public expenditure consideration

Public expenditure can play an important role in managing uncertainty. In particular, initial public spending on transformational projects can have high marginal benefit in dispelling uncertainty, thus reducing this bias toward inaction and providing appropriate conditions for the evaluation of 'following' investments, including participation from private sources. Thus transformational investment may be considered a critical role for governments in shaping markets and creating preconditions for private participation.

This principal is well illustrated by a recently published report on positive tipping points by the University of Exeter (positive tipping points). In the context of sustainable transformational change, we can think of the ‘tipping point’ as the moment a cleaner option becomes the default because reinforcing feedbacks take over. Government investment in systems transformation is crucial for reaching such tipping points, as individual projects are unlikely to reach them in isolation and so risk being undervalued.

The Exeter report emphasises that clean technology mandates which provide certainty for businesses, investors and consumers can be some of the most effective ways to reach positive tipping points, enabling faster transitions in multiple sectors. Government action and expenditure to enforce mandates such as those discussed in the report would dispel uncertainty and so allow a more representative and valuable quantitative analysis.

Within the Green Book framework, we therefore believe it is valuable to give consideration to these 'real options' within transformational systems, acknowledging that the current application of Real Options Analysis may be limited in current practice and challenging when there is high uncertainty. Nonetheless, exploration and appropriate credit for these potentials may provide decision-makers with supplementary information for evaluation where high uncertainty may justify less reliance on purely quantitative measures.

Section 3: Transformational change and the Green Book

The Green Book is the government's guidance on assessing the costs, benefits and risks of different options to achieve government objectives. It currently includes a definition of transformational change and supplementary guidance which is relevant to the appraisal of transformational projects.

Challenges of evaluating transformational change within the Green Book framework

We have identified some key characteristics of transformational change which create challenges when applying the Green Book's current evaluation systems:

1. By nature, they exhibit high levels of **uncertainty -** in trying to create a radical change they are operating in a paradigm for which there is no existing well established precedent; and

2. The **system-based** nature of the change, by which associated benefits would emerge in creating synergies including for potential projects not in existence, such as reducing barriers to entry for new sustainable technologies; and

3. The **long-term** nature of benefits of a transformational system, which means that even if benefits were able to be quantified reliably, their value which emerges in the long-term are mathematically discounted heavily compared to short term projects under the current Green Book approach

4. For certain transformational systems, **delayed action can increase the ultimate cost** of making the transformation (e.g. cost of mitigating climate change).

Characteristic of transformational change	Challenges within current Green Book methodology	Key considerations
High levels of uncertainty	Uncertainty by its nature defies quantitative assessment. The high reliance users of the Green Book often place on quantitative assessments such as cost-benefit analysis risks undermining the decision-making it underpins.	• Increase emphasis on qualitative assessment criteria for transformational projects relative to those which elicit marginal change, and reduce reliance on cost-benefit analysis and the economic case. • Incorporate scenario analysis and other more uncertainty driven quantitative assessments. • Recognise the value of initial investments that reduce uncertainty in the system.
System based nature of change	The Green Book assesses projects on an individual basis and evaluation criteria assumes that they elicit marginal change. However, systems-based change can fundamentally change the system being appraised which calls into question the very assumptions underpinning their assessment. There is	• Assess the value of transformational systems as a collective, and not on an individual project basis, for example using the carbon curve to assess the benefits from carbon reduction/ transitional projects. • Where individual projects are assessed, evaluate co-benefits as part of quantification approaches.

	also a danger of benefits unlocked by the transformation not being allowed for.	
Long term nature of benefits	Under the current discounting approach the value of long-term benefits are mathematically discounted heavily compared to short term projects, which makes them appear less valuable.	• Reconsider the discounting of all projects to ensure a fair assessment of long term benefits and target intergenerational fairness. • Consider a lower discount rate for appraisal of transformational projects (relative to other projects), noting their unique characteristics. • Explicitly assess the cashflows from inaction to compare to the cost of investment.
Escalating costs of late action	For certain transformational systems, delayed action can increase the ultimate cost of making the transformation (e.g. cost of mitigating climate change). This is contrary to the underlying principles of the Green Book discount rate, in particular the application of the wealth effect.	

Figure 2 - Challenges of assessing transformational change with Green Book methodology

The appraisal of transformational systems

Within Green Book guidance, transformational systems and projects are appraised using the same five case model as applies to projects which elicit marginal change. This includes the economic case, which is assessed via cost benefit analysis.

Figure 3: The five-case model - source: Master the Better Business Case 5 Case Model for Project Success

The five case model is designed to provide a holistic approach to assessing projects. Despite this, concerns remain that in practice users of the Green Book place a higher reliance on the economic case (including cost benefit analysis and net present values) than its authors intended.

Since the last Green Book review in 2020, the Green Book has taken several positive steps to acknowledge transformational change, long-term horizons, and broader place-based and / or systemic impacts. This includes the following:

- **Transformational Annexes and Guidance** - for system-changing projects, departments are encouraged to assess systemic effects, identify *cross-project synergies* (e.g., EV charging +

grid upgrades + renewables), and apply *scenario analysis* to test multiple plausible futures. These tools are not yet a substitute for Cost Benefit Analysis (CBA), but provide additional lenses to capture value that narrow Net Present Value calculations may miss.

- **Guidance on Place-Based Appraisal** - emphasises assessing *regional impacts* and distributional effects, consistent with the government's "levelling up" agenda. For example, infrastructure in less prosperous regions may not rank highest in national Cost Benefit Analysis terms, but could still be justified by its contribution to reducing inequality and supporting regional growth.

These approaches appear to address concerns with assessing transformational projects on a robust and comparable basis. However, in practice, we understand that many of these supplementary approaches remain underdeveloped and inconsistently applied. In addition, the supplementary guidance available is applicable to only a subset of transformational projects, rather than being general guiding principles for transformational change as a whole. There is potential for wider reform to expand and standardise further these approaches to improve the consistency of assessments for programmes and projects that have high uncertainty associated with transformational and systems change.

Overall, we consider that the current Green Book approach remains most suitable for project-specific, marginal analysis supported by discounting within cost benefit analysis, and continues to leave transformational projects at risk of undervaluation.

Section 4: Discounting and the Green Book

The role of discounting

Discounting is a technique used to place a current value on cashflows expected to occur in the future. The higher the discount rate, the lower the current value placed on future cashflows.

Discounting is central to the Green Book's approach for economic appraisal, ensuring that costs and benefits occurring at different points in time can be compared consistently. Through comparing a single value rather than projected cashflows, this can simplify ranking and prioritisation of a range of different projects. Particularly where long time-horizons are involved, appraisal results for projects can be very sensitive to the discount rate chosen. This makes it a key assumption with the potential to materially influence decisions around project selection and the spending of public money. It also means that the choice of discount rate is not just a technical one — it's also a policy decision that must reflect society's priorities.

The Social Time Preference Rate (STPR)

The current Green Book uses the *Social Time Preference Rate (STPR)* as the discount rate. Its purpose is to convey how society values present versus future consumption. Whilst the derivation of the STPR is complex, it can be broadly considered as based on three core elements:

Element of the STPR	Value	High level description
Pure social time preference (δ)	0.5%	Reflects society's assumed preference for consuming now rather than later.
Catastrophe risk (L)	1%	Reflects the assumed impact of risks external to the project which may have a material impact on project outcomes and / or lead to project failure
Wealth effect (μ × g)	2%	Accounts for the expectation that future generations will be richer, and thus future costs more affordable. Also assumes diminishing marginal utility, i.e. we value further increases less as we consume more.
Overall STPR rate	**3.5%**	

Figure 4 - Summary of STPR components and values

Together, these components give a headline 3.5% discount rate. However, there are precedents in existing Green Book methodology to vary the discount rate 1) when appraising different types of projects, and 2) over different time horizons. There is also a precedent for requiring discount rate-based sensitivity analysis as part of the project appraisal process.

Circumstances set out within the Green Book where adjusted discount rates are used are as follows:

- To account for increasing duration based uncertainty in the nature of its components, the Green Book applies a **declining schedule to the discount rate over time**.
- **The 'wealth effect' element of the STPR is not applied to health benefits** as we are assumed not to apply a diminishing marginal utility (ie value future increases less the more we have) when considering improvements to life / health.
- Where the possible effects of an intervention being examined as part of an appraisal are long term and involve very substantial or **irreversible wealth transfers between generations**

(including irreversible changes to the natural environment) the Green Book requires further sensitivity analysis to be undertaken. This involves applying both the standard Green Book discount rate and a reduced discount rate (excluding pure social time preference) to costs and benefits.

Allowing for these exceptions, a summary of STPR rates is set out below, illustrating how each rate / sensitivity rate declines over time.

Discount rate to use	Years from appraisal date		
	0-30	31-75	76-125
STPR (standard)	**3.50%**	**3.00%**	**2.50%**
STPR (standard) with irreversible wealth transfer sensitivity	*3.00%*	*2.57%*	*2.14%*
STPR (Health benefits)	**1.50%**	**1.29%**	**1.07%**
STPR (Health benefits) with irreversible wealth transfer sensitivity	*1.00%*	*0.86%*	*0.71%*

Figure 5 - Summary of declining discount rates in Green Book. Rates continue to decline beyond 125 years.

The graphic below shows the smoothly declining rate set out in the OXERA report referenced by the Green Book, alongside the actual discount rates adopted for different time periods in Green Book guidance.

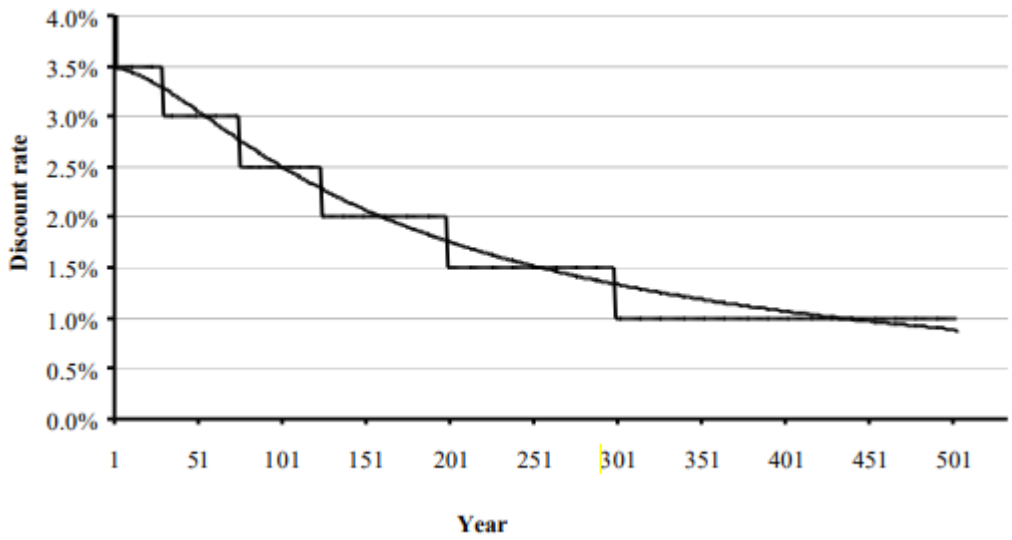

Figure 6: Declining discount rate schedule - source: OXERA report

Key assumptions and reasoning underpinning the declining discount rate are as follows (see OXERA report for further detail):

- Empirical observations of individuals' social time preference rates displayed a declining discount rate.
- Mathematical analysis by Newell and Pizer taking into account the uncertainty in future discount rates determined a smoothly declining rate.
- The long-term discount rate was set to tend towards the lowest conceivable discount rate, which was determined to be 1% p.a..
- The time-steps have been chosen mostly arbitrarily to simplify their application in policy rather than using a continuously decreasing discount rate. The initial 30 year time-scale was based

on the longest time horizon for government bonds, which are considered to be a reliable measure of relatively predictable economic conditions.

Further discussion on the declining rate is set out in section 5.

Discounting in practice - Environment Agency case studies

As part of our research we engaged in discussions with the Environment Agency to better understand how the discount rate impacts their project appraisal. Following this, we performed discount rate sensitivities on two real life Environment Agency funded projects. We are extremely grateful to both to the Environment Agency for agreeing to share their data, and to Arup for their work in providing the anonymised datasets, without whom this analysis would not have been possible.

The sensitivities we have undertaken have involved varying:

- the headline (ie start) discount rate; and
- the rate of decline (encompassing both the time-steps between declines in the discount rate and the size of decrease at each time-step).

Alongside these sensitivities we have also calculated the duration of costs and benefits of these projects. The duration is a measure of the time until the average cashflow occurs, and will therefore be higher for projects with a long time-horizon than a short one. See Appendix B for further explanation of the definition of duration and example calculations.

The main conclusions from our work are as follows, with further detail set out in Appendix A:

- A project with a higher benefit duration and a higher gap between its benefit duration and cost duration is more sensitive to discount rate changes (both to the headline discount rate and the rate of decline respectively) relative to a project with lower durations.
- For the sensitivities we have chosen, project BCRs (benefit-cost ratios) are far more sensitive to changes in the headline discount rate, than to adjustments to the declining rate. This is due to the fact that changes to the headline rate impact all cashflows, whereas changes to the declining rate only impact cashflows that occur further in the future than the first time-step for a rate decline.

Section 5: Discussion of factors relevant to the discount rate

With many different and often inter-related considerations to take into account, setting an appropriate STPR is far from straight forward. Understanding the context and purpose in which the rate will be used is essential. Judgement is also required to balance theoretical correctness, whilst avoiding spurious accuracy.

Whilst the discount rate affects the appraisal of all projects, as noted in section 2, transformational projects are more severely exposed to the discounting effect relative to projects with more marginal impacts, due to the often long-term nature of benefits they unlock.

Pure social time preference

This aspect of the discount rate is often viewed as central to intergenerational fairness considerations. As explained in section 4, it is currently set to $\delta = 0.5\%$ to reflect society's preference for current over future consumption.

The Stern Review, which is referenced in the current Green Book, has already advised that the pure time preference should not be applied to projects that involve irreversible wealth transfers from the future to the present. The Green Book currently suggests performing a sensitivity of setting $\delta = 0\%$ for these projects but stops short of requiring the social time preference to be removed from baseline calculations.

Many other economists, including Frank Ramsey (who created the Ramsey formula), have argued that to ensure intergenerational fairness a 0% rate should apply to all projects. We believe that this consideration is likely to be particularly relevant for transformational projects, as they are seeking to make changes to the present system which will impact future generations more than our own.

This means that transformational projects or long term investments, will by their very nature have a higher weighting on valuing these later future benefits. Applying an additional preference for current over future consumption, will through its nature undervalue the benefits from these types of project, and understate the value of transformational change, when comparing different projects' benefits.

The wealth effect

The wealth effect is proportional to an assumed ‘best estimate’ increase in real per-capita consumption growth over the medium to long term. Whilst this is not identical to GDP growth, they are likely to be highly correlated and due to limited data on real per-capita consumption growth we have instead focused on GDP as the wealth effect indicator.

Putting to one side the question of whether GDP is appropriate to be used as a proxy for the growth in societal wealth (an approach that over time has faced challenge from many academics and economists), the wealth effect is a key part of the STPR. Of relevance:

1) at 2% it represents more than half of the overall discount rate and

2) its current calculation is proportional to assumed real per-capita consumption growth for which we have used GDP, the central assumption of which is highly sensitive to climate outcomes, as a proxy.

GDP growth expectations

The current Greek Book estimate of a 2% growth rate uses the post-war period between 1949 and 1998. While we recognise that accurate economic forecasting of growth is incredibly difficult, we are concerned that a 2% p.a. growth assumption for GDP may no longer be realistic, and may overestimate actual future GDP growth.

Some economists argue that the recent past is more relevant to future growth, while others argue that only long time horizons can pick up the full range and frequency of potential economic outcomes. If we take the recent past approach, the average annual GDP growth from 2000-2019 (to exclude the COVID-19 period) was 1.7%. Over the longer time horizon from 1830-2009, Groom and Maddison (2018) estimate that per capita consumption growth was only 1.1%.

In terms of future forecasts, figure 7 below shows the short-term estimates of annual GDP growth according to the Office for Budget Responsibility (OBR), alongside an average of 14 external forecasts such as those by Bloomberg Economics and Capital Economics.

GDP (percentage change)					
2025	2026	2027	2028	2029	
1	1.1	1.4	1.5	1.5	Average of external forecasters
1	1.9	1.8	1.7	1.8	OBR estimate

Figure 7: Short-term estimates of p.a. GDP growth - source: May 2025 Forecasts

If we take into account the long-term past growth rates, recent growth rates, short-term external forecasts, as well as the increased uncertainty of future growth rates when taking into account potential climate change outcomes, then we believe that a lower estimate of 1.5% p.a. growth rate would be more suitable.

Climate uncertainty

Over recent years our understanding of climate change driven uncertainty has matured significantly. We now know that unlike in circumstances where we expect past trends to continue, many plausible climate outcomes for our world could result in material deviations from our usual ‘best estimate’ assumptions.

For example, a plausible range of global temperature increase is between ~1.4 to 3 degrees above pre industrial levels by 2060 (NGFS climate scenarios), and there is a high level of uncertainty surrounding increased frequency of extreme weather events and early ecosystem tipping points such as coral bleaching or permafrost thaw.

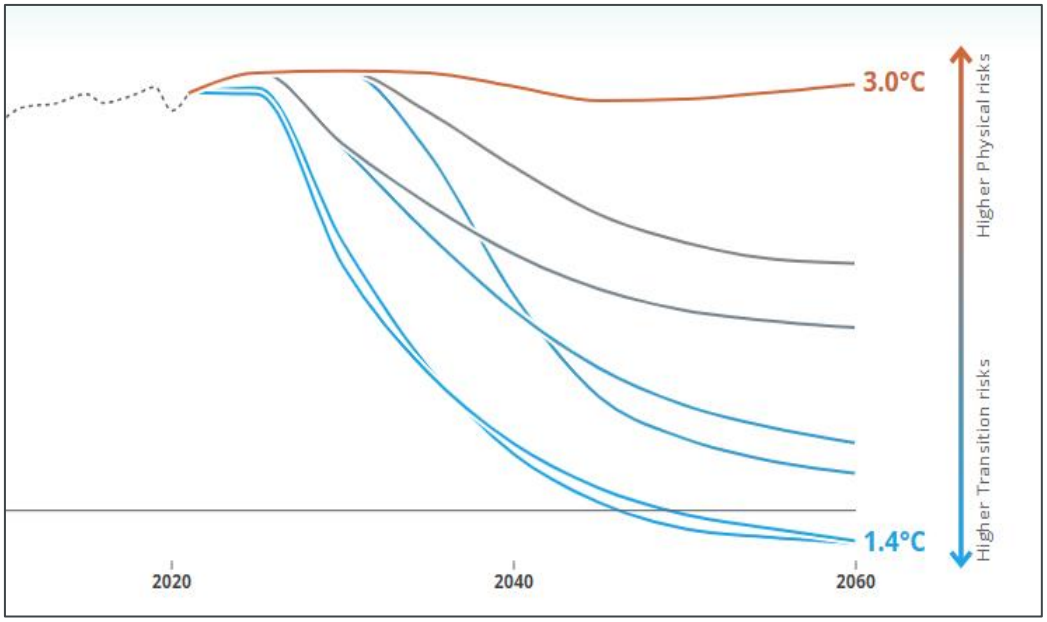

Figure 8: NGFS scenarios temperature outcomes - source: NGFS Scenarios Portal

Due to many complicated interlinking factors, uncertainty in global climate outcomes are mirrored in economic and financial ones. Accordingly, there is considerable climate driven uncertainty in the wealth effect, including over shorter time-scales than 30 years.

Implications for GDP

The OBR produces the UK's projections for GDP growth, with their most recent projections here. Over medium to long time-horizons the OBR's projections reflect a central 'best estimate' for GDP growth incorporating a range of variables.

In its 2025 fiscal sustainability report the OBR incorporated climate scenarios considering how climate outcomes may impact medium to long term GDP growth. This positive development emphasises the need for climate considerations to be taken into account wherever GDP is used to inform, or part inform, public sector assumptions.

The graph below shows the impact of climate change damage on GDP compared to a no-climate-change baseline scenario. This impact includes changes to the economy and public finances through three main channels: mitigation of climate change, damage from climate change and adaptation to climate change.

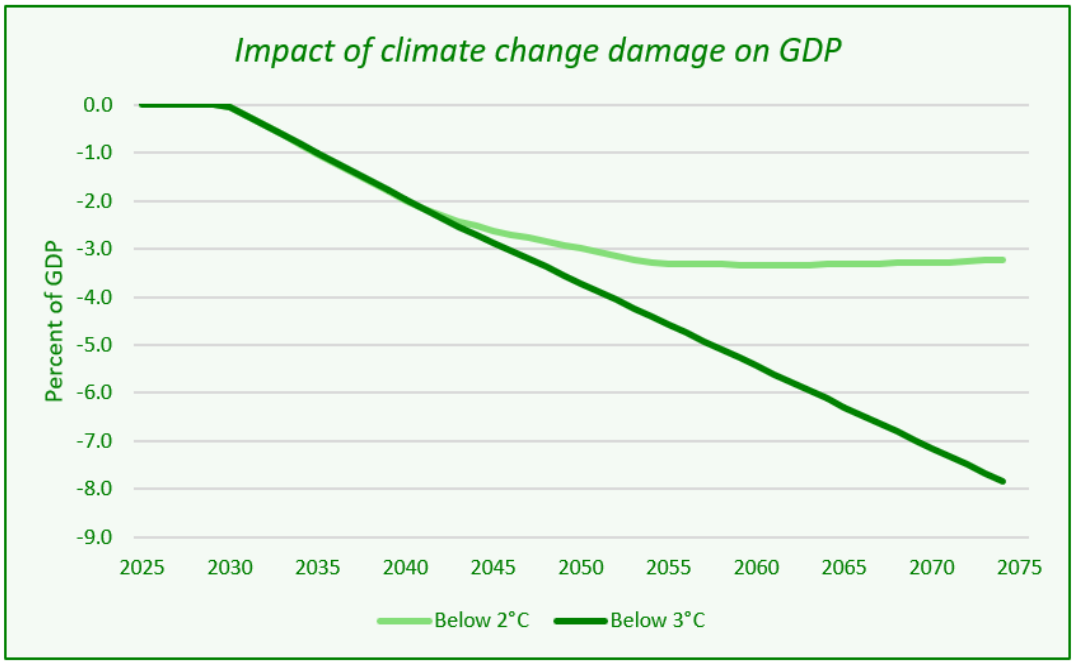

Figure 9: The Impact of climate change damage on GDP - source: Fiscal risks and sustainability

The climate scenarios the OBR has considered are based on output from the Network for Greening Financial Systems (NGFS). However, it is also important to note that the NGFS scenarios have been subject to much scrutiny and accusations of underestimating the impact to GDP that may occur. Many other scenario providers predict far larger drops in GDP, particularly under the most severe warming scenarios. In addition, the IFoA's widely publicised Planetary Solvency Report notes that estimates may significantly understate the full range of potential downside risks associated with physical risks.

A consensus message, however, is that GDP may diverge significantly from our 'best estimate' projections over the long term. And the most extreme risk outcomes may be catastrophic. Hence where a discount rate, such as the STPR, is set by reference to GDP, stakeholders must be prepared to consider the impact on their project objectives if GDP were much lower than our current estimates would suggest, including the possibility for negative growth (ie de-growth).

The risk distribution and intergenerational fairness

In practice there can be no 'correct' discount rate meaning that some risk must be borne by both current and future generations. Intergenerational fairness implies that the rate is chosen such that the risk born by each generation is broadly equal.

Particularly where a single value STPR is used, to assess whether intergenerational fairness exists, it is essential to consider how costs and benefits are borne between different generations across **the entire risk distribution, including allowing for the most extreme risk outcomes**. For the wealth effect this means assessing the plausibility that growth in societal wealth that differs from the 2% p.a. assumption.

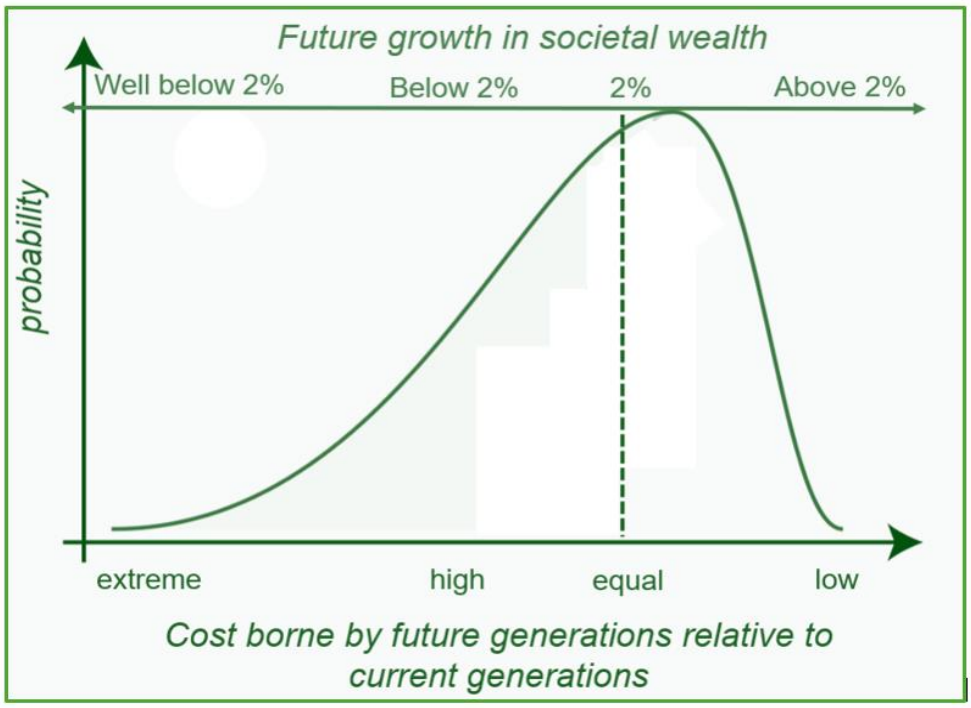

Figure 10: Wealth effect risk distribution and intergenerational implications

The skewed distribution above allows simplistically for the impact of climate uncertainty on the wealth element of the STPR. As illustrated by the graphic, even if the STPR is set such that 'average' risk is assumed to be broadly similar:

- There is a smaller range within the higher growth (above 2% p.a) outcomes. If these outcomes occur future generations will benefit, as they will more easily be able to afford the costs left to them, whilst maintaining additional wealth to spare.
- There is the very real potential for extreme negative (well below 2% p.a) growth outcomes. This would result in significantly higher financial and societal costs being borne by the future generations relative to our own.

As present day decision makers we have an obligation to ensure future generations are not disadvantaged by the decisions we make in which they have no say. This includes a moral obligation to not exposing future generations to risk extremes such as those climate change creates. How to achieve this in practice is not easy, but being aware of the risk distribution and its implications is an important first step.

Implications for the declining discount rate

The existing rate of decline is based on work by economists Newell and Pizer from a report published in 2001. Their report based the uncertainty in discount rate on the US market real interest rates for long-term, high-quality government bonds of that time.

However, it is important to note this work does not take into account any possibility of future interest rate behaviour differing from past behaviour. Whilst this approach may have been reasonable in 2001, we now know that past data is unlikely to be a reliable indicator of future economic conditions, especially when taking into account climate change uncertainty which is unprecedented in past data.

Newell and Pizer's work was validated in part by work by Weitzman in 2002, which is referenced in the OXERA report, and produced similar results. Weitzman's work was based on a survey of 2800

leading economists who were asked to state what discount rate they thought should be used to appraise long-term projects to mitigate climate change.

Taking into account climate damages and broader economic uncertainty, and using a skewed risk distribution as in figure 10, we believe that if the Weitzman survey or the Newell and Pizer analysis was to be repeated today, it may result in a range of possible future discount rates with greater uncertainty, a more highly skewed distribution, and a lower mean. This would result in a discount rate schedule which would decline at a faster rate and towards a lower long-term rate.

Section 6: Key recommendations

Discount rate related recommendations

In light of our research and conclusions, we have several recommendations in relation to the discount rate underpinning existing cost benefit analysis calculations. We have designed these to be simple and easy to implement, building on the existing precedents for varying the discount rate by benefit type and duration, as well as the use of discount rate sensitivities.

1) **For <u>all projects</u>:**

   a) *We recommend that HM Treasury add a sensitivity to remove the wealth effect from calculations. This would enhance the evidence base available to decision makers by allowing them to understand how BCRs would be impacted if future growth in wealth is much lower than the central assumption assumes, including helping with understanding intergenerational fairness implications.*

   b) *We recommend that HM Treasury revise the growth rate assumption underpinning the wealth effect of the STPR to 1.5% p.a. instead of 2% p.a.. This recommendation is based on the long-term historical rates, recent rates and short-term forecasts discussed in section 5.*

   c) *We recommend that HM Treasury revise the declining discount rate schedule to account for updated estimates of future interest rates and growth rates, taking into account greater uncertainty in possible future growth rates, and the possibility of much lower growth rates than previously anticipated. This may for example include,*

      a. *Using a lowest conceivable long-term growth rate of 0% rather than 1% (though we would also acknowledge that it may be possible to argue for the lowest conceivable discount rate to be negative).*

      b. *Repeating the analysis to set the declining discount rate (potentially using similar methodology to the work by Newell and Pizer) using up to date and informed estimates of possible future interest rates and growth rates. We believe this may result in a discount rate which declines at a faster rate. Going forwards we recommend that this analysis should be repeated periodically (at least every 10 years) or when circumstances change which impact the view of future interest rates and growth rates.*

   d) *We recommend that HM Treasury revise the current time-scales for the declining discount rate to reflect higher short / medium term uncertainty due to the impacts of climate change.*

      Whilst there are many ways this goal could be achieved we suggest an appropriate revision may be to halve the existing time-frames, so the first rate decrease would be after 15 years. This would allow for the increased uncertainty in the wealth effect meaning it can no longer be projected with confidence over the initial 30-year time-scale.

   e) *We recommend further evaluation of the wealth effect, which is currently based on per capita consumption growth, in a climate change context. Per capita consumption, similarly to GDP (which is a measure of production within the economy), is a 'flow' variable measuring consumption occurring on an annual basis rather than a 'stock' variable measuring the absolute level of wealth. Measurement of the 'stock' of wealth is*

particularly relevant in a climate change context, where, despite ongoing consumption flows, the downside risk of environmental destruction could result in a large erosion of real wealth and future consumption capacity which would only emerge much more slowly via a measure such as per capita consumption. In these cases, it would be possible to have a net decrease in wealth while consumption remains positive. Therefore, the investigation of an appropriate 'stock' measure is recommended as to create greater responsiveness to real erosion of wealth, and by extension, prevent the intergenerational shifting of wealth and the burden of investment which might otherwise occur.

2) **For projects <u>identified as transformational under HM Treasury guidance:</u>**

   a) *Unlike marginal change projects which are assumed to be cheaper if undertaken later, due to escalating costs of inaction, many transformations are likely to be cheaper if undertaken now rather than in the future. Therefore we recommend that HM Treasury adopts a lower discount rate for standard benefits associated with transformational projects, relative to non-transformational projects. Our recommendations for transformational projects are as follows:*

- *social time preference rate:*
  - *our primary recommendation is for this to be removed from the baseline calculation of benefits.*
  - *our secondary recommendation would be for this to be removed for a sensitivity calculation, and to place a greater weighting on this sensitivity calculation when making decisions than for non-transformational projects.*
  - *Our tertiary recommendation would be for this to be removed for a sensitivity calculation with equal weighting given to the sensitivity as the sensitivity for non-transformational projects.*
- *wealth effect:*
  - *our primary recommendation is to adopt a lower headline rate and/or a faster declining profile (which tends towards a lower long term rate) for the wealth effect even if this is not implemented for other projects in line with recommendation 1.*

3) **Enhance the evidence base for discounting impacts**

Whilst pursuing theoretical and academic accuracy is valuable, we also recommend that HM Treasury builds up a stronger evidence base to understand how discounting is impacting decision making in practice within Departments and Public Bodies.

To help achieve this, we recommend that users of the Green Book are asked to calculate the duration of annual costs and benefits for their projects both pre and post discounting. The financial duration is a measure of the average time until cashflows are realised, and is calculated from a stream of cashflows. A simple example highlighting how financial duration is calculated is set out in Appendix B.

We believe this would be a simple and quick addition to current calculations. Users of the Green Book would then be better able to understand the impact discounting is having on project selection (including when choosing which from a portfolio of viable projects to fund) and identify any inherent biases toward short termism driven by discounting. HM Treasury could also request this information from Departments / Public bodies to better understand current implications, increase transparency and adopt ongoing evaluation and iterative improvements to discounting approaches as required.

4) **Undertake additional research to assess intergenerational fairness implications of the Green Book discounting approach**

We recommend that HM Treasury works to enhance its understanding of the interaction between discounting and intergenerational fairness, building on the commentary set out in section 5. We also recommend that HM Treasury works to clearly define HM Government's intergenerational risk appetite, including establishing the maximum burden of risk that our present society are prepared to allow to be transferred to future generations. Some potential mechanisms that could be explored to improve intergenerational fairness include:

- *A (negative) margin for prudence to the discount rate to acknowledge the skewed nature of the distribution,*
- *a discount rate sensitivity threshold tied to HM Government's risk appetite, where any projects whose Benefit Cost Ratios fall below a specified level under that sensitivity may be discarded, even if their non-sensitivity scorings are high.*

Non discount rate related recommendations

As we noted in our introduction, discounting is embedded into the broader project appraisal system. To ensure the true value and scale of transformational benefits are allowed for we recommend that any changes to the discount rate should be undertaken in conjunction with the following recommendations:

1) **Carving out what counts as transformational**

When considering alternative analysis approaches for transformational projects, it will be essential to clearly define the types of projects to be deemed transformational. At present the Green Book definition of transformational projects is relatively generic and subject to interpretation.

We recommend that HM Treasury incorporate into the Green Book a clear framework for establishing which projects are to be identified as transformational, using a top down approach by defining key systems changes required and their implications, and setting out concrete examples to guide users.

2) **Reduce reliance on quantitative measures when appraising transformational projects**

It has long been a concern that users of the Green Book often place an over reliance on cost benefit analysis. Noting the uncertainty associated with this analysis for all projects, particularly over long time horizons, we would emphasise the importance of challenging this mindset and embedding consideration of all 5 investment cases.

This mindset shift is particularly important for transformational projects, where there is higher uncertainty, and the transformation itself is changing the system being analysed. For transformational projects we recommend clear guidance that, due to inherent uncertainties, the economic case - in particular cost benefit analysis - should form a smaller proportion of the decision making criteria than for other projects.

3) **Embed assessment of co-benefits for all transformational projects**

To build on existing guidance and encourage consistency of approach to transformational appraisal, we recommend that HM Treasury produces a clear and succinct principles-based framework to underpin the assessment of all transformational projects. For maximum impact this should be embedded in the main Green Book and not a supplementary guidance document.

We believe that a useful starting point for this framework could be the 'Triple Dividend of Resilience' approach used to assess climate adaptation projects (see table below). This would

encourage acknowledgement of the existence of co-benefits, and support analysts to assign quantitative values to them (where possible) when cost benefit analysis is undertaken.

	Triple dividend of resilience approach for climate adaptation projects (taken from table 9, page 29 here)	*Potential for adapting three tier approach for wider adoption in transformational guidance*
First dividend / tier	**Avoided losses**	**Project benefits / avoided losses**
	The reduction in damages from climate change that would have occurred without adaptive action (for example, the reduction in productivity loss from overheating)*	The benefits and avoided losses that would not have occurred without the project taking place.*
Second dividend / tier	**Dynamic market benefits**	**Unlocked investment and benefits**
	Dynamic market effects such as induced investment and productivity gains independent of climate change (for example, investing in flood barriers can enhance investor confidence and boost local economy).	Induced investment and productivity gains unlocked which are independent of the initial transformational project (for example investing in regeneration of an area can enhance investor confidence and boost local economy).
Third dividend / tier	**Social and environmental benefits**	**Social and environmental benefits**
	Wider social welfare benefits from adaptive measures (for example, improved habitats for biodiversity, wellbeing gains from natural landscapes being protected).	Wider social welfare benefits from transformational measures (for example, improved health impacts associated with reduced carbon emissions).

** The first tier represents the project specific benefits and avoided losses that underpin traditional cost benefit analysis*

Figure 11 - Adapting the triple dividend of resilience approach to apply to all transformational projects

Appendix A: Discounting case studies

As set out in section 4 we have performed discount rate sensitivities on two real life Environment Agency funded projects. Whilst data has been anonymised to protect the identity of the projects in question, a general description of each is set out below.

> ***Project A (project lifespan 50 years)-*** *The scheme aimed to enhance flood resilience in a northern UK town by reducing flood risk to properties and infrastructure while ensuring no adverse impact downstream. Key interventions included refurbishing and replacing ageing flood defence assets along a major river, introducing sustainable landscaping in a local park, and implementing environmental improvements in the surrounding catchment. The scheme also supported regional economic regeneration and environmental goals such as biodiversity enhancement and carbon sequestration. The asset life of the intervention is 50 years.*
>
> ***Project B (project lifespan 100 years)*** *- Flooding from a local river previously affected numerous residential properties and recreational facilities in a UK town, with a concentration of properties at risk in a particular area. The scheme aimed to develop a Strategic Outline Case for a viable flood risk management scheme that also delivered environmental benefits, addressing the lack of formal defences and limited flood warning time. Without intervention, flooding was expected to worsen due to climate change, impacting both the residential and recreational spaces and worsening risk to life. The preferred way forward was a targeted intervention by raising localised embankments around the most vulnerable areas. The asset life of the intervention is 100 years.*

Under a standard Green Book discounting approach the headline discount rate (ie discount rate at time 1) is 3.5% and the lowest rate floor (i.e. the discount rate the declining rate tends toward) is 1%. The full summary of discount rate sensitivities we performed are as follows:

Sensitivity runs	Headline rate maximum	Headline rate minimum	Decline at each timestep	Timestep for decline	Discount rate floor
1	3.5%	1%	0.5%	In line with Green Book (ie first decrease after 30 years)	1%
2	3.5%	1%	0.5%	Halve Green Book timescales (ie first decrease is after 15 years) **	0%
3	3.5%	1%	0.7%*	In line with Green Book	1%
4	3.5%	1%	0.7%*	Halve the Green Book timescales**	0%

**For illustrative purposes we have assumed that the rate that tends to 0% at the same speed as the existing rate tends to 1%.*

***For illustrative purposes we have assumed that the decline in the rate at each timestep remains constant even when the timescales for each decline are reduced. In practice it may not be realistic and a reduction in timesteps may be combined with a lowering in the rate of decline.*

Figure 12 - summary of sensitivities undertaken

We have also calculated the financial duration of the costs and benefits respectively. As expected, project B (with asset lifespan of 100 years) has higher benefit durations than project A (with asset lifespan of 50 years). A table setting out the respective (pre discounting) durations for each project is below.

Project	Lifespan of intervention	Cost duration	Benefit duration
A	50	4.7	26.3
B	100	2.5	52.0

Figure 13 - summary of project durations

Exploring changes to the headline rate

The graph shows the percentage change to project BCRs with a headline rate of between 3.5% and 1%, decreasing in steps of 0.5%. It illustrates that:

- projects with higher duration of benefits, are more sensitive to reductions in the headline discount rate
- the larger the reduction in headline discount rate the higher the impact on the BCR.

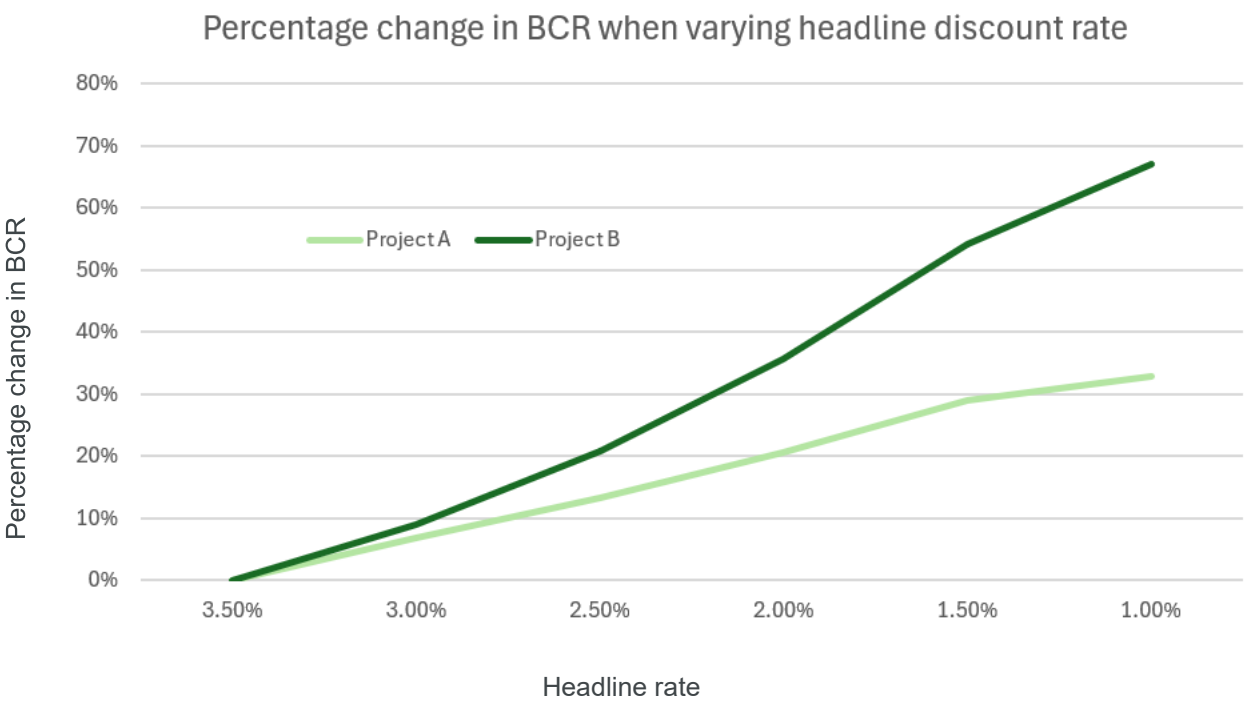

Figure 14 - graph showing % change to BCR for different headline rate sensitivities

Exploring changes to the declining rate

The graph shows the percentage change in project BCR for each of the sensitivity runs. In each case the headline discount rate is 3.5%. It illustrates that:

- projects with higher duration of benefits, are more sensitive to reductions in the declining discount rate; and

- for the sensitivities we have chosen, increasing the speed of decline has a greater impact on project BCRs than lowering the discount rate floor to 0%.

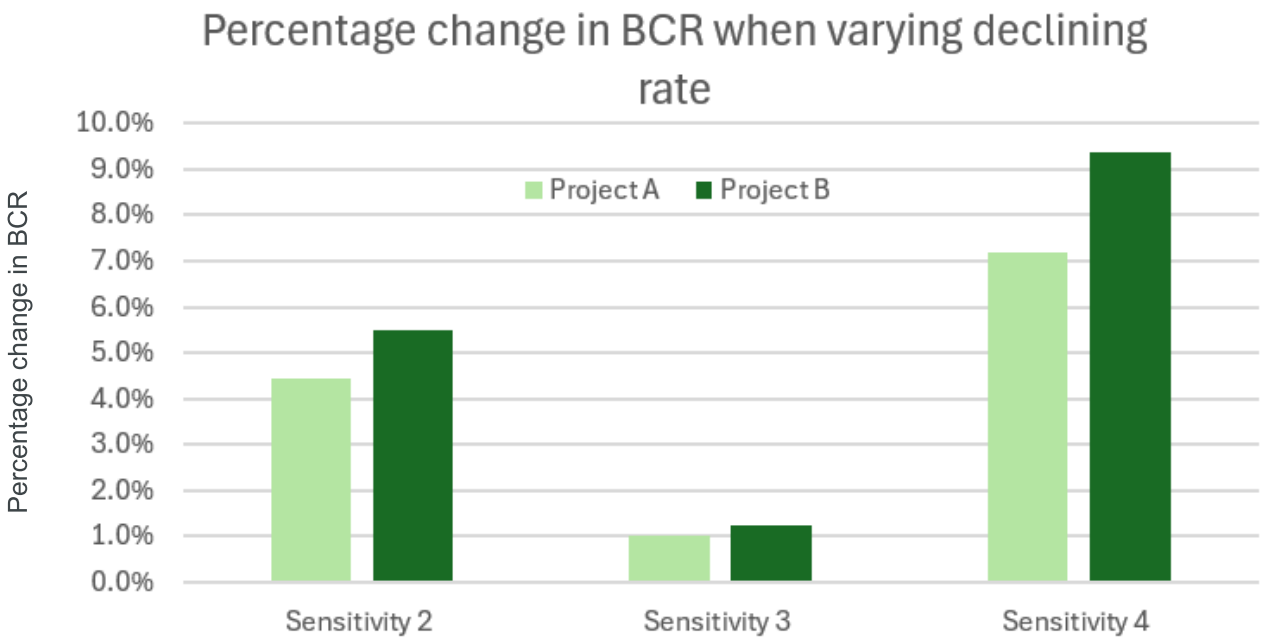

Figure 15 - graph showing % change to BCR for different declining discount rate sensitivities

Appendix B: Duration example calculations

The financial duration is a measure of the average time until costs or benefits from cashflows are realised, and is calculated by taking the average of the times of a stream of cashflows weighted by the present values of the cashflows.

Calculation method

Suppose a project involves present value cashflows $C_1, C_2, \ldots, C_n$ occurring at times $1, 2, \ldots, n$ respectively. The duration is then calculated as follows:

$$Duration = \frac{\sum_{i=1}^{n} i \times C_i}{\sum_{i=1}^{n} C_i}.$$

Example calculation

Consider a project with a lifespan of 5 years which involves the following cashflows (in PV terms):

1. Investments required (ie costs):
    - Initial investment of £2 million at time 0
    - Maintenance costs of £0.5 million per year
2. Social and financial benefits gained (ie benefits):
    - Ongoing benefits of £2 million per year for life of project

Calculating the cost duration: The table below summarises the relevant cashflows and sub calculations required to calculate the costs duration:

Year cashflow occurs (i)	0	1	2	3	4	5
PV of cashflow (C)	2	0.5	0.5	0.5	0.5	0.5
Weighted cashflow (i) x (C)	0	0.5	1	1.5	2	2.5

The cost duration is then the sum of weighted cashflows (ie 7.5) divided by the sum of PV cashflows (ie 4.5) = 1.7 years. **This illustrates that, on average, costs are paid 1.7 years into the project.**

Calculating the benefit duration: The table below summarises the relevant cashflows and sub calculations required to calculate the benefit duration:

Year cashflow occurs (i)	0	1	2	3	4	5
PV of cashflow (C)	0	2	2	2	2	2
Weighted cashflow (i) x (C)	0	2	4	6	8	10

The benefit duration will be the sum of weighted cashflows (ie 30) divided by the sum of PV cashflows (ie 10) = 3 years. **This illustrates that, on average, benefits are realised 3 years into the project.**

Appendix C: References

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