Residual Values and Appraisal Period in Multimodal Transport Appraisal

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Executive Summary

Background

- ITS was commissioned by DfT to provide a short think piece on residual values and appraisal period, including a rapid review of the relevant literature and conceptual framework(s). This is a contribution to DfT's work[1] considering the potential value of transport investments over the very long term, beyond the usual appraisal period.
- In the UK, the default appraisal period for infrastructure projects is currently from project start until 60 years after opening[2]. The impact of some transport interventions is likely to extend to 100 years after opening or beyond, however longer term impacts are particularly subject to uncertainty. At the heart of this note is the aim to tackle the core questions on residual value while at the same time recognising and highlighting the inter-relationships with the treatment of uncertainty, which are the subject of other research for DfT.
- DfT set seven questions for this think piece to answer, but also indicated that the approach and structure was for the authors to decide. This document contains a Review (Section 2), and a section on the Conceptual Framework and Applications (Section 3). The answers to the seven questions are then provided at the end of the document (Section 4), based on the work done.
- In completing the work, we consulted academic and industry experts across six countries including the UK, and undertook a quick survey of practice in other UK Government departments[3]. We gratefully acknowledge all of those involved, for the helpful and substantive responses received.

Residual Values

- Residual values (RVs) are a standard part of CBA theory and methodology[4]. Their purpose is to capture the value remaining at the end of the appraisal period, and they can be applied when, for example:
    - a standard appraisal period is used (e.g. the standard 25-30 years used by the European Commission[5]) that is shorter than the useful economic life of the project;
    - a shorter appraisal period is used for procurement/commercial reasons, e.g. when a rail service will be franchised over 15 years; or
    - the project consists of multiple components, with different asset lives that do not all come up for replacement/renewal at a common point in time.
- The use of RVs in transport appraisal is uneven across the other countries and regions surveyed for this paper (Netherlands, Sweden, US, Australia, New Zealand, EU), and also differs across UK sectors (education, defence, business, environment). Nevertheless, there are examples of practice and methodology which DfT could draw on.
- The Netherlands is one country that uses an appraisal period longer than 60 years for transport infrastructure: the default is 100 years and RVs are not used to extend that, however RVs can be used in cases where a shorter appraisal period has been set. Elsewhere, including the US, Australia and the EU, RVs are used to extend the CBA beyond the standard appraisal period – where justified by the useful economic life of the assets created (or modified) by the project.

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[1] DfT (2020b)
[2] HM Treasury, 2020, §2.18
[3] a workshop was also held to discuss the findings with DfT, Highways England, rail industry and academic experts on 23.2.2021
[4] e.g. Boardman et al. (2018), de Rus (2010)
[5] EC (2014), or the standard UK appraisal period for infrastructure, of 60 years (HM Treasury, 2020, §2.18)

Methods to Calculate Residual Value

- There are two major distinctions in the literature on RVs, which are to some extent related:
  - the appraisal context: economic vs. financial; and
  - methods used to calculate the RV: 'economic' (net benefits-based) vs. 'accounting' vs. 'market based' methods.
- *Economic methods* essentially provide the present value of future net benefits – the term 'economic' is used in the same sense as the 'Economic Case' in DfT's Transport Analysis Guidance (TAG)[6] and the Treasury Green Book[7]. These methods naturally include:
  - user benefits, carbon savings and other categories of benefits in the appraisal;
  - ongoing costs – including operating and maintenance costs, and renewals.
- In the economics literature, a strong case is made for the use of economic methods to calculate RV in an economic CBA (e.g. Boardman et al., 2018). Also in some previous transport appraisal guidance, the recommendation is to use economic methods to calculate economic RVs (e.g. Mackie et al., 2005b).
- In contrast, the most common *accounting method* uses straight-line depreciation of the capital costs to generate an RV. This method is widely used in asset valuation in the transport sector[8], and in financial planning. It is also sometimes used in economic appraisal as a proxy for the full residual value[9]. There is relatively little support in the economics literature for the use of this method in an economic context (e.g. Boardman et al, 2018; Jones et al., 2013/14; De Rus, 2010 are not supportive), however it is used in practice as a proxy for the economic RV in several countries/regions/institutions – the reason for this, we believe, is that it is straightforward to calculate and can be interpreted as a 'lower-bound' or 'conservative' estimate of the full RV.
- The challenge facing anyone arguing for the use of the economic method, is to demonstrate that it, too, is feasible and proportionate. We have explored this and reached some working conclusions (below).
- Finally, the idea has been raised of using *market based methods* to calculate the RV. Clearly markets exist for transport vehicles and other equipment, and it is true that markets also exist for the sale or lease of transport infrastructure[10]. Market data can help to predict the resale or scrap value of assets, based on those for similar assets, particularly in the near term. These values are directly relevant in financial appraisal, or in economic appraisals over relatively short time horizons – such as a 15 year rail franchise or 30 year concession – where sale/transfer/lease of assets is part of the plan.
- There is a problem, however, which is particularly acute for infrastructure: the gap in time between the economic appraisal being carried out and the hypothetical sale of assets at the end of the appraisal period, could be 70 years or more[11]. Current market data is limited in what it can tell us about the value of infrastructure assets in, say, 70 years' time. Market participants and analysts may be able to offer a judgement, however the economic appraisal will usually take a different perspective on the discount rate, risk attitude and planning horizon, and will have a wider scope (including a range of economic, environmental and social impacts). Therefore calculation of an RV is likely to require a set of analysis specifically for economic appraisal purposes, to which market data would be just one form of input.

[6] https://www.gov.uk/guidance/transport-analysis-guidance-tag
[7] HM Treasury (2020)
[8] e.g. Highways England (2020d), *Financial Statements for the year ended 31 March 2020*
[9] e.g. in the US, Australia and in EU projects
[10] e.g. HS1 (NAO, 2012), various bridge, tunnel and toll road concessions, and rail franchises
[11] e.g. if construction takes 10 years and the operating period is the UK standard 60 years for infrastructure

Conceptual Framework, Evidence and Applications

- Section 3 of this paper explores the conceptual framework for residual values, covering:
  - setting of the *appraisal period*;
  - *calculation* of RVs;
  - economic *asset lives* for transport assets;
  - the role of *rights of way*, land ownership and other very long-lived components in transport projects;
  - *future options* created by investment in new rights of way and transport assets;
  - the impact of *risk and uncertainty* on long-term appraisal.
- A worked example is provided, to help consider the feasibility – and challenges – of implementing the two main alternative methods for RVs: economic net benefits and straight line depreciation (Section 3.8). Implications for comparability across projects and modes are also discussed (in Sections 3.4-3.6). Having worked through all of this, it becomes easier to address the central questions 'when, and how, should RVs be used in transport appraisal'? The main findings are as follows.

Setting the appraisal period

- According to the literature[12], for a project or plan the appraisal period should be set to capture the useful economic life of the longest-lived asset created (or modified) by the project.
- Under risk and uncertainty, the appraisal period is also limited by the time period over which sufficient demand can be foreseen[13]. Further, discounting implies that that beyond some horizon, contribution to NPV may be insignificant – depending very much on the growth rate of benefits versus the discount rate (e.g. see Figure 5).
- Finally, a government body may choose to set a standard appraisal period for certain types of projects (e.g. the 60 year operating life for infrastructure) for comparability reasons, and may take into account the factors above in choosing the length of that period.

When should RVs be used?

- The literature is clear that there is a case *in principle* for calculating RVs whenever the useful economic life of the longest-lived asset created (or modified) by the project is longer than the appraisal period. This would be the case if the appraisal period is set at a lower level, e.g. the 60 year operating life for infrastructure, while the expected asset life is longer. Again, the case for a particular RV period would need to take into account risk and uncertainty, and the effect of discounting.
- In practice, it would be helpful for appraisers to have a rule of thumb to indicate when RVs are needed in the Economic Case. The New Zealand method[14] states that the appraisal should aim to capture at least 90% of the whole-life net benefits (PVB) and costs (PVC). The PVC will rarely be an issue as transport projects do not tend to have large back-end costs (unlike, e.g., nuclear power plants), however a 90% PVB target could be considered by DfT as a guide to when RVs are needed in transport appraisal[15].

Asset lives

- Evidence is available from Highways England, other infrastructure managers and literature sources, on the expected asset life for different categories of transport assets (summarised

[12] e.g. Boardman et al. (2018); Mackie et al. (2005a,b)
[13] for the project to remain open. The quantity of demand is usually estimated by a combination of forecasting and extrapolation/linking to population growth for longer term projections. This will also be subject to scenario analysis with the uncertainty toolkit.
[14] Table 3
[15] and how long the RV period should be

in Table 9). This will be useful in the early stages of appraisal, for smaller projects and generally as a benchmark. Project-level evidence may also be available on expected asset lives – particularly for projects with a more developed Business Case[16].

- Section 3.4 and Table 9 show that some important[17] categories of transport infrastructure assets, including earthworks and some structures, have a useful economic life in the region of 100 years. Therefore there is at least a theoretical case for a 40 year RV period for infrastructure (61-100 years after opening). The worked example suggests this may also be justifiable in practice, subject to the degree of uncertainty to be introduced with the uncertainty toolkit, in different contexts.
- Other assets (and project components) such as rights of way and land, may be viewed as perpetual – however this will be moderated by other criteria, such as risk/uncertainty and the effect of discounting. For the moment we assume a 40 year RV period, and note that there is scope for further research on this issue.
- Asset life data also provides the information needed to set roll-over intervals for the shorter-lived project components in the CBA. In our worked example this applies to, e.g., train sets (35 years), as well as various infrastructure components.
- Overall, knowledge of asset lives should not be a barrier to implementation of RVs.

Risk, uncertainty and growth rate data

- In order for appraisers to implement an economic (net benefits-based) approach to RVs routinely, our work suggests that certain gaps would need to be addressed, chiefly: i) methods to quantify risk and uncertainty; and ii) provision of growth rates for key variables over a long-enough time interval. DfT has already noted in its consultation document[18] that uncertainty over benefits and costs in the long term is a key issue with any extension of the appraisal period. We understand that DfT is moving to a position where uncertainty should be captured using scenarios (in the uncertainty toolkit[19]), particularly on the demand side. Techniques to reflect the risk-adjusted value of scheme costs are already in place (TAG Unit A1.2) but need to be extended to future costs (e.g. renewals). Promoters of large projects are familiar with quantifying demand side risks (e.g. traffic risk, revenue risk) but these methods have not yet been recommended as standard in TAG. These changes seem worth considering as a package.
- The TAG Data Book already provides projected growth rates for values of time, safety and environment, and for population, up to the year 2100. For routine use of the economic approach to RVs, a slightly longer time series is needed – probably into the 2130s – and some additional series including cost indices would be useful. The challenge in providing growth rates for key variables is again linked to the tools for representing uncertainty over the long term.

Rail example

- The paper uses a worked example to bring out the implications of applying RVs in detail. A 100km fast rail line is chosen as an example of a project where questions around a longer appraisal period or the use of RVs are likely to arise. The structure of the costs and benefits is developed from recent High Speed Rail projects, particularly HS2, but assuming lower line speeds and capital cost requirements per km of line.
- For the economic approach, the worked example assumes a +15% risk adjustment to the costs in the RV period, and a 15% negative risk adjustment to the benefits – these are illustrative (see Section 3.8). We also projected forward construction and maintenance cost indices and made other necessary assumptions.

[16] e.g. HS2 Ltd. (2012) Table 8
[17] important as a % of capital expenditure on projects
[18] DfT (2020b)
[19] e.g. using the Common Analytical Scenarios when available

Table ES1: RV example – results for the economic approach and straight-line depreciation

Appraisal Period	60 Yrs	60 Yrs + RV (Econ)	*RV Risk Adjustment*	60 Yrs + RV (Econ) with Risk Adjustment	60 Yrs + RV (Depreciation in PVC)	60 Yrs + RV (Depreciation in PVB)	100 Yrs
PVC (BTB), £m, PV	7091	7091		7091	7091	7091	7212
PVB, £m, PV	12033	12033		12033	12033	12033	16051
RVC (61-100), £m, PV		121	*15%*	139	-616		
RVB (61-100), £m, PV		4018	*-15%*	3416		616	
BCR	**1.70**	**2.23**		**2.14**	**1.86**	**1.78**	**2.23**
ΔBCR, %		31%		26%	10%	5%	31%

- Among the main implications are:
  - using the methods defined in the literature, it is feasible to calculate an RV for the years 61-100 from the opening year;
  - in the TAG framework, it is not sufficient to measure the Net Benefits each year in the economic approach (as in the literature), since costs and benefits in the RV period will fall into different parts of the BCR – hence a separate 'RVC' and 'RVB' will be needed;
  - that resolves the issue of whether RV should be added to the PVB or deducted from the PVC (an issue in international practice), when the economic method is being used;
  - including the economic RV increases the BCR from 1.70 to 2.23 in this worked example – the effect of the risk adjustments (to demand and costs) is to reduce this back to 2.14;
  - the RV calculated using straight line depreciation and a 'component approach' (Jones et al., 2013/14) is much smaller, reducing the BCR by around 0.3 relative to the economic approach in this case;
  - if the negative risk adjustment to the RVB (residual value benefits) was increased to the point where the economic and depreciation approaches are equalised, this would require a large -64% risk adjustment to the RVB;
  - risk adjustment matters, but if it can be quantified, the economic net benefits approach *may* still produce substantially larger benefits than straight line depreciation (as well as being theoretically more consistent) – this is an empirical question;
  - the 'component approach' is feasible (and preferred) when using a depreciation method.

Comparability across projects and modes

- There is a great deal of consistency across modes, in terms of the asset lives of the key asset categories for determining the RV period (earthworks, structures), and the presence of 'perpetual' components such as rights of way and land (Sections 3.4-3.6). The evidence does not support shorter asset lives for walking and cycling projects, or for rail, for example.
- In order to achieve comparability between projects with different asset lives (30 versus 60 years, for example), the rollover method has advantages over the Equivalent Annual Net Benefit (EANB) metric[20] because it allows DfT to continue using BCR as the main value for money metric (Section 3.5).

[20] Boardman et al. (2018)

Options

- Experience shows that some types of infrastructure can be – and have been – re-used for other modes and purposes (examples are given in Section 3.7 – including many disused railways). As a result there may be positive option value associated with certain types of new infrastructure in specific locations. In principle this could be included as part of the long-term benefits (in the RV). Since this could not be foreseen with certainty at the appraisal stage, it might be represented using a decision tree or a real options approach. The feasibility of including this in appraisal would require further thought.
- Other relevant types of options include: options to decommission infrastructure (e.g. the return of the A3 at Hindhead to nature); and the option to defer investment to a later date when demand may be greater. The latter is part of the Do-Minimum branch of the decision tree. Again, a real options approach could be pursued to gain an overall measure of the value of the full set of conditional outcomes.

Financial Appraisal

- Although the main focus in this think piece has been the Economic Case in transport appraisal, there are other applications for RVs. EC (2014) addresses the use of RVs in financial appraisal, and here accounting measures are appropriate because the aim is to capture the value to the asset owner, not to capture the whole of the public value.
- A notable UK application is the Residual Value Mechanism (RVM). This was introduced by DfT in 2015, to incentivise passenger rail franchisees to invest in franchise assets which do not have a commercial return within the life of the franchise – but do if the subsequent franchise period is included. The transfer value of the asset or scheme, from one franchisee to the next, is based on an assumption that the asset will be fully depreciated over a defined period (asset life), and straight line depreciation is applied from purchase through transfer to the end of the asset's life.
- In general, there is a rationale for using RVs in the Financial Case when it is expected that at some point the assets will be sold or transferred, marking the end of the financial appraisal period. Alongside this, the role of depreciation-based asset valuation in financial accounting has already been noted.

Criteria for the Use of RVs

- Finally, some thought was given to what the criteria are for the use of RVs. DfT's questions asked what is appropriate – this is an attempt to provide a checklist against which the emerging methods/future appraisal guidance could be judged:
  - theoretically justified?
  - practically feasible?
  - proportionate? i.e. does the benefit in improved decision making outweigh the costs of implementation?
  - no perverse incentives created?
  - best available method?

Answers to DfT's Questions, and Conclusions

- The answers to DfT's seven key questions require a careful balance of the factors discussed above: the answers are set out fully in Section 4. Some further, general conclusions are drawn in Section 5.

1. Background

DfT is currently consulting on the **appraisal period** and use of **residual values** in TAG[21]. In the foreword to their consultation document, DfT writes:

> "The government has ambitious plans for transforming the nation's infrastructure over the coming decades, with a number of major transport projects already underway or in the development pipeline. These have the potential to deliver benefits for decades, if not hundreds of years to come. It is therefore essential that we are able to understand and represent long-term potential benefits within transport scheme business cases, in order to inform robust, evidence-based decision making.
>
> One key analytical assumption is the length of the appraisal period used to assess project benefits, typically 60 years at present. Many projects have the potential to deliver benefits well beyond this time horizon, but these benefits are not currently included in scheme appraisals. Indeed, many historical investments in transport have had a lasting legacy far beyond 60 years. Set against this, there is inevitably greater uncertainty associated with benefits in the longer term. This is driven by uncertainty around future demand, the condition of the transport system and 'unknown unknowns' such as fundamental technological change or climate risks." (DfT, 2020b, p5)

ITS was approached by DfT to tender for the provision of a short think piece on this topic. DfT sought a short expert/academic review of the relevant literature and conceptual framework(s) for considering the potential value of transport investments over the very long term, beyond the initial appraisal period.

The brief was that the piece should be principles-based and cover all forms and modes of transport investment in theory, with specific consideration of existing practice for road, rail, active mode and other public transport appraisals.

The work addresses (but is not limited to) seven key questions, as requested by DfT, as follows:

1. Whether and when it is appropriate to consider the residual value at the end of any given appraisal, whether that is the current maximum of 60 years, or a potentially longer period.
2. How should residual values be best calculated within transport appraisal? In particular:
    a. Under what conditions might residual values reflect the wider social and economic benefits of assets?
    b. Are there any methods or approaches which would allow us to reflect the wider social and economic benefits of an asset when calculating residual values?
3. Related to (2), what are relative merits, or otherwise, of 'market based' valuation approaches which seek to value the right to run a transport service as a concession, or the value of the infrastructure manager.
4. Alternative potential approaches for calculating residual values in appraisal and their strengths and weaknesses, both in theory and with regards to practicality of implementation.

21 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/942396/appraisal-periods-consultation.pdf

5. The implications of different approaches to appraising residual value for the comparability of appraisal results across different modes and schemes.
6. The extent to which different approaches to residual valuation can accommodate the full range of expected welfare effects, including social, environmental and wider economic benefits.
7. What approaches are taken in other countries and industries for reflecting residual values in appraisal/investment decision making?

The structure of this document is as follows. The review findings are contained in section 2. We then go on to address the conceptual framework, and then consider the application of this to different modes and application types (section 3) and finally answer DfT's questions (section 4).

2. Review

The first part of the brief was to provide a short review of the academic and grey literature. We have extended this to include a rapid survey of practice in selected countries, updating the information in the International Comparisons of Appraisal Practice study for DfT (Mackie and Worsley, 2013), and have gathered information on current practice elsewhere in Whitehall. This helps to assess the overall picture in practice, rather than relying too heavily on a small number of studies.

In this section of the report, we cover:

- 2.1 Literature on Residual Values and Appraisal Period for Transport Infrastructure
- 2.2 Current DfT and HM Treasury Guidance and Practice
- 2.3 International Appraisal Practice
- 2.4 Other Sectors in UK Government
- 2.5 Main Findings

2.1 Literature on Residual Values and Appraisal Period for Transport Infrastructure

Residual values – role in CBA, definition and approach

Residual values[22] are a standard part of cost-benefit analysis (CBA) theory and are found in the theoretical frameworks set out in most CBA texts (e.g. Boardman et al., 2014/18; de Rus, 2010). Their use in practice is far from universal, as our findings show, but in principle they have a relatively clear place in CBA, which is to capture any significant value remaining at the end of the appraisal period.

The definition of residual value in the literature usually takes one of the following two forms, which are related although not necessarily identical:

a) residual value represents the *value of the asset (or assets) remaining* at the end of the appraisal period[23]; or
b) residual value represents the *value of all subsequent net benefits*, after the end of the appraisal period[24].

One way in which these two definitions can be reconciled is to take an economic view of the 'value of the asset(s)', by calculating the present value of the net benefit stream from the asset(s), including any external net benefits (environmental or social benefits, for example) and discounting at the Social Time Preference Rate (STPR). The subject of valuation of public sector assets is addressed, for example, by Lowe (2008), who states that the Green Book[25] is "written primarily from the standpoint of assessment of new spending proposals", but the same principles can be applied to asset valuation when required for public decision making – and goes on to outline how this should be done. The CBA texts follow essentially the same approach – when a residual value is needed, the preferred approach is an 'economic' one based on the stream of discounted net benefits.

[22] Alternative terminology found in the literature includes 'terminal value' and 'horizon value' (e.g. see Boardman et al., 2014, p144/157).
[23] This is the definition underlying EIB & EC (2005), for example.
[24] This is the over-arching definition given by Boardman et al. (2014/18), for example.
[25] HM Treasury (2020)

Residual values can be used in financial appraisal as well as in economic appraisal[26]. EC (2014), for example, discuss both the economic and financial role of residual values in transport appraisal. In the case of financial appraisal, the principles are different: the aim is to capture the remaining financial value of the assets created by the project – usually via a 'market-based' method or an accounting method (both of which are outlined below) – and to quantify any implications for financial flows[27].

Appraisal period and residual value

The established principle in CBA is that the appraisal period should reflect the expected economic life of the longest-lived asset created, in order to capture the whole net benefit stream (e.g. Boardman et al., 2014/18; de Rus, 2010; Mackie et al., 2005a). This allows for 'rolling-over' of the shorter-lived assets within the appraisal period (e.g. periodic replacement or renewal of road surfaces, railway rolling stock, etc.). In transport appraisal guidance, this is usually subject to certain balancing considerations, including:

- the desire for comparability across projects;
- uncertainty around the longer-term cost and benefit streams;
- the risk of technical obsolescence specifically; and
- contractual periods of private participation, such as franchises or concessions[28].

We will show in section 2.3 how these considerations limit the appraisal period in most countries, and in section 3 we will bring in evidence on the asset lives of transport infrastructure components by mode.

If it is accepted that the appraisal period chosen may be less than the maximum asset life within the project (e.g. 60 years < 100 years), there is scope to consider whether/how to quantify the value remaining between the end of the appraisal period and the end of the project lifetime, $PV(H_k)$. This is the residual value.

$$NPV = \sum_{y=base}^{k} \frac{B_y - C_y}{\prod_{i=base}^{y}(1+r_i)} + PV(H_k) \quad (1)$$

where

NPV is the project's Net Present Value;

$PV(H_k)$ is the present value of an amount H_k at the end of the appraisal period[29];

y is the year (and i is a separate year count from the base year to the year y);

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[26] corresponding to the Financial Case and the Economic Case in UK 'Green Book' appraisals (HM Treasury, 2020).

[27] Note that projects can impact on the financial accounts of organisations both through:

i. the statement of financial position, or balance sheet – showing assets and liabilities;
ii. the income and expenditure, or cash flow statements – reflecting a change in financial flows as a result of the project.

This is true for publicly-owned infrastructure authorities as well as fully commercial businesses. The HM Treasury Guidance on the Financial Case indicates that these impacts should be reported (HM Treasury, 2018, p9).

[28] these last two considerations are due to de Rus (2010, p125).

[29] Note that the residual value $PV(H_k)$ is discounted, while the undiscounted H_k is also sometimes referred to as the residual value.

By and *Cy* are the benefits and costs (as defined in TAG) in year *y*;

r_i is the social discount rate in year *i*;

k is the last year of the appraisal period.

Residual value methods

Boardman et al. (2018) identify five different methods to calculate the residual value:

i. extrapolation of net benefits – this can be over a finite future or in perpetuity (also known as 'annuity method' and 'perpetuity method' respectively – Jones et al., 2013);
ii. salvage/liquidation value – of the assets at the end of the appraisal period, if a market exists;
iii. depreciation – this may be geometric or straight-line, we review the options below;
iv. arbitrary share (%) of construction cost – the authors acknowledge this is a simplistic approach not based on economic or financial principles, and we do not envisage DfT selecting this option;
v. setting the residual value to zero – by setting the appraisal period so that it matches the stream of net benefits.

We found this list the most complete and the most helpful in the literature. The **first** and the **fifth** methods are closely related (and numerically equal), but presentationally different (see Table 1). Both follow the ***economic principles*** – this is essentially an extension of the approach taken during the appraisal period to the years after the end of the appraisal period. The fifth method is a special case, where the appraiser (e.g. DfT) has the flexibility to extend the appraisal period to match the end of the net benefit stream.

Table 1: Example of Methods Based on Economic Principles (i. and v.)

Method	Appraisal Period	Residual Value Period	PVB	PVC	BCR
i.	2021-2085	2086-2125	PVB during Appraisal Period £315m Residual Value £28m	£174m	1.97 or 1.81+RV
v.	2021-2125		PVB during Appraisal Period £343m	£174m	1.97

Note: appraisal period based on, e.g. 5 years construction + 60 years operation; residual value period assumes useful economic life of the project is 100 years from opening.

If the net benefits during the later years are more uncertain, that might be a justification for separating these out. For example, method i. may be preferred to method v. if DfT decided to place the Residual Value into the Evolving Monetised Impact or Indicative Monetised Impact category of the Value for Money Framework (DfT, 2017a, Box 4.3/4.4).

The second, third and fourth methods relate to the valuation of assets (definition (a) above). The **second** is a '***market based' approach***, and it is worth noting that there are cases of transport assets being sold by the public sector to the private sector in recent years, for example the sale of the Government's 40% stake in Eurostar International Ltd. in 2015 for £760m, the 30 year concession on HS1 granted to Borealis Infrastructure and Ontario

Teachers' Pension Plan for £2.1bn in 2010[30]. The earlier privatisations of airport operator BAA plc in 1986 and the (short-lived) privatisation of Railtrack plc in 1994-2002 are other notable examples.

The concept here is that the remaining assets may be sold at the end of a project, and the value realised may be used as the residual value. Boardman et al. (2018) note two important caveats:

- that the method will not capture any external benefits or costs (e.g. wider economic impacts, environmental or social benefits);
- that it requires a well-functioning market for the asset in order to derive a value.

We would add that a 'market-based' approach in *ex ante* appraisal would require forecasting of the future market value several decades ahead[31]. This problem is particularly acute for infrastructure: the gap in time between the economic appraisal being carried out and the hypothetical sale of assets at the end of the appraisal period, could be 70 years or more[32]. Current market data is limited in what it can tell us about the value of infrastructure assets in, say, 70 years' time.

There certainly an international market for ownership of transport infrastructure assets[33]. Market participants and analysts may be able to offer a judgement, and that should be useful in forecasting demand, and building a financial appraisal, particularly over shorter periods – e.g. a 15 year rail franchise or 30 year infrastructure concession[34]. However, an economic appraisal will usually take a different perspective on the discount rate, risk attitude and planning horizon, and will have a wider scope (including a range of economic, environmental and social impacts). Therefore, particularly over the longer term, calculation of an RV is likely to require a set of analysis specifically for economic appraisal purposes, to which market data would be just one form of input.

The **third** method is based on ***depreciation of the assets*** from their initial capital cost. The concept here is that: "Depreciation is the change in value associated with the aging of an asset. As an asset ages, its price changes because it declines in efficiency, or yields fewer productive services, in the current period and in all future periods" (Fraumeni, 1997), or depreciation is "the decline in value due to wear and tear, obsolescence, accidental damage, and aging" (Katz and Herman, 1997).

Boardman et al. (2018) draw a distinction between an economic approach to depreciation and an accounting approach. The economic approach is represented by an econometric literature which seeks to identify the profile of depreciation for different assets (e.g. Fraumeni, 1997, contains theory and US evidence). These empirical studies tend to find that the value of assets declines geometrically (in compound fashion).

[30] Financial Times (2010)

[31] Boardman et al. (2018, p154) do not state this explicitly, but instead state that: "In practice, it is difficult to determine the liquidation value of some government assets. Clearly, there is often no market for a used highway, and even if there were, the market value would probably not reflect the discounted value of future net social benefits".

[32] e.g. if construction takes 10 years and the operating period is the UK standard 60 years for infrastructure

[33] PWC (2015)

[34] e.g. the Second Severn Crossing whose nominal concession length was 30 years – actual transfer back occurred after 21 years, when the agreed revenue had been collected.

By contrast, accounting depreciation is usually based on accounting rules – which are designed for financial accounting not for economic appraisal. The most common form is straight line depreciation, where the starting value is the initial capital cost and the remaining asset value declines linearly up to the end of the expected asset life. To determine the value at some intermediate point, such as the end of the appraisal period, it is possible to interpolate linearly.

The issue with the accounting approach is that it "may bear no relationship to the actual economic usefulness of the asset"[35]. However the practice in appraisal – across sectors – is very strongly oriented towards the use of 'straight-line depreciation'. There is a tension here which is not fully resolved by any of the literature in the review we have undertaken.

Energy networks is one sector in which this topic has been given more in-depth consideration. Analysis by CEPA/SKM/GL Noble Denton for OFGEM (2010) found that despite the available alternatives, straight line depreciation was appropriate for electricity networks given the expected profile of usage in the alternative future scenarios considered (i.e. "high throughout the period"). For gas networks, they would still recommend straight line depreciation *or* some "front-end loading" of the depreciation profile given "significant policy risk if the shift to electric space heating takes place" (p3).

Table 2: Recommendations to OFGEM on asset lives and depreciation profile

Sample	***Depreciation asset life***	***Depreciation profile***
Electricity transmission	45-55	Straight-line or back-end loaded
Electricity distribution	45-55	Straight-line or back-end loaded
Gas transmission	45	Straight-line or front-end loaded
Gas distribution	45	Straight-line or front-end loaded

Source: CEPA/SKM/GL Noble Denton for OFGEM (2010)

Another case of depreciation being tied to usage is in the Dutch airport sector where we understand that depreciation 'per unit' of demand over the asset life has been used[36].

Overall, this is indicative of – as far as we can see – the widespread use of relatively simple approaches to asset value depreciation. Simple approaches often have advantages in applicability and auditability, which may help to balance any theoretical loss of accuracy. Having chosen a depreciation approach in principle (e.g. straight line depreciation), there are then some very important details which emerge in the application of it – this can be seen in the asset valuation methods used by transport authorities (e.g. Highways England), which we will explore in Section 3.

As already noted, the **fourth** method identified by Boardman et al. (2018) for calculating RVs is completely arbitrary and therefore of little use to DfT without further theory or evidence to support it. We will not consider it further.

[35] Boardman et al. (2018, p155)
[36] CEPA/SKM/GL Noble Denton (2010)

Jones et al. (2013/14) 'Transport infrastructure project evaluation using cost-benefit analysis'

Jones et al. (2013/14) are an interesting pair of documents that provide a survey of recent examples of RVs in the transport infrastructure sector, and describe the methods used. Their conclusions are that: "the treatment of residual value (RV) is inadequate and needs further research. The current methods for calculating RV do not properly reflect the true value".

Jones et al. (2013, 2014) classify the methods used as follows:

- Straight-line depreciation;
- Annuity/perpetuity methods;
- Component method

The annuity and perpetuity methods presented by Jones et al. are simplified and restricted versions the economic, net benefit-based methods described by Boardman et al. (2018). Perpetuity methods are a special case where the useful asset life is infinite (perpetual). The 'component method' is a refinement of the straight-line depreciation method, but also raises some interesting wider questions.

Straight-line depreciation

The straight line depreciation method assumes that depreciation of an asset occurs based only on age and at a constant rate. Therefore the RV is calculated as a proportion of the initial capital cost of the asset (Jones et al., 2014):

$$RV = \frac{Remaining\ Asset\ Life}{Asset\ Life} x\ Initial\ capital\ cost \qquad (2)$$

Note that their formula omits discounting, which will also be required in CBA. Also that there is no specific provision to adjust the capital cost to a common price base year (e.g. 2010 in TAG).

According to this method, when an asset has reached the end of its useful lifetime, RV is zero. Therefore, RV can only be non-zero if it has remaining useful life at the end of the appraisal period.

Annuity method

This is equivalent, in broad terms, to the economic approach in Boardman et al. (2018). Jones et al., however, assume a constant annuity, that is a fixed annual net benefit *(B-C)*, rather than a variable stream of new benefits. This is neat presentationally, although does not fit particularly well with the likely reality – including growth of benefits over time due to value of time growth (for example), or the renewal intervals of different assets over time which create an uneven cost profile.

$$RV = (B - C)\frac{1-(1+r)^{-RL}}{r} \qquad (3)$$

where

RV is the residual value, measured in the last year of the appraisal period and requiring further discounting from there back to the base year (e.g. by 60+ years) – this RV is not a Present Value;

(B-C) is the annuity (fixed annual net benefits after the appraisal period, until the end of the asset life);

r is the discount rate;

RL is the number of years' remaining asset life, after the appraisal period.

This can also be expressed as

$$RV = Aa_r^{RL} \tag{4}$$

where

A is the annuity;

a_r^{RL} is the annuity factor, for a period *RL* at a discount rate *r*.

These formulae are also restrictive in that they assume a constant discount rate, which is incompatible with the UK's stepped discount rate profile (HM Treasury, 2020b, p122). We provide formulae for the UK in the Conceptual Framework section below (Section 3).

Perpetuity method

The perpetuity method is a special case of the annuity method, for use where it is judged that useful economic life of the project is infinite, and the annual net benefit *(B-C)* can be confidently projected forward over an infinite future. In that case, the RV would be an approximation to the infinite stream of net benefits after the appraisal period:

$$RV = \frac{(B-C)}{r} \tag{5}$$

(Again, note that this is not discounted to the base year, but back to the last year of the appraisal period).

The applicability of this is limited because:

- while we may be confident that some of today's infrastructure will still be present in 200 or 500 years, the use to which it is put, and therefore the benefit, *B*, is much harder to confidently quantify. We are surrounded by pieces of railway and canal infrastructure that are no longer used for railway services or waterborne freight. Some of them have found a new use (see Section 3), whose value may differ substantially from *B*, and some are unused.
- while the line of some Roman Roads is still present, many of them are in use as tracks/trails, or they have been regraded and realigned in order to meet the needs of modern vehicles. It is worth asking searching questions about what kinds of infrastructure – if any – we can be confident will be used over the very long term (see Section 3).

Component method

Finally, if the straight line depreciation method is adopted, then the question can be asked: should the residual value be calculated for *all* assets, or should the calculations be focused on the long-lived assets? The latter has some appeal, since we are using the capital cost and asset life of specific assets to generate an RV estimate, and only some of the assets created by a project will usually extend into the residual value period.

Jones et al. (2013/14) argue for a component-based approach. It is not universally practised, and DfT would probably want to take a view one way or the other on this point, if the straight line depreciation method is adopted.

Jones et al. review of practice

The work by Jones et al. (2013/14) also offered an overview of previous practice around RVs in the transport field, in which the key points were that:

- in practice, when it was used, RV was often defined by the infrastructure lifetime and the depreciation profile; and
- RV was sometimes calculated separately for the different components of the infrastructure – EIB & EC (2005), ACT (2008) and RITES & Silt (2010) being examples of this practice.

2.2 Current DfT and HM Treasury Guidance and Practice

The Green Book does not provide detailed guidance on how residual values should be calculated. However, it does include a brief section giving a definition of residual value as 'the opportunity cost of the asset at the end of the appraisal period', including its market price at that time, and some general principles (HM Treasury, 2020, p58, emphasis added):

"6.11. An asset's residual value or liability at the end of the appraisal period should be included to reflect its opportunity cost. Residual values do not depend on the actual sale of an asset. ***The market price at the end of the asset's lifetime*** *– the best value obtainable from its sale, lease or alternative use* ***– is part of the value*** *created as a result of the cost to the public sector of creating the asset.*

6.12. ***Contingent liabilities*** *– potential future expenditure if certain events occur –* ***should be appraised and included as part of the expected cost of risk****. They sometimes result from decisions that do not involve direct public expenditure. One example of a contingent liability is the cancellation costs if a public sector organisation terminates a contract prematurely. The HM Treasury contingent liability approval framework provides further discussion on calculating expected costs.*

6.13 ***Depreciation is not included in the estimate of Net Present Social Value (NPSV)****, although it is included in the estimate of public sector costs in financial analysis. Depreciation is used in accounting to spread an allowance for loss in value of an asset over its lifetime. In calculating NPSV, costs are not spread over time but register when total costs are reflected in the accounts."*

The Green Book also allows for a longer appraisal period in certain cases: "A longer appraisal period may be suitable where intervention is likely to have significant social costs or benefits beyond 60 years. This should be agreed with the approving authority. Possible examples include immunisation programmes, the safe treatment and storage of nuclear waste or interventions that reduce climate change risks" (§5.15).

We have already noted the difficulties with a market-based approach to residual value. Going forward, it would be useful to have clear guidance on the measurement of residual value, covering the Economic Case and the Financial Case, and including (but not limited to) the specific issues addressed by 6.11-6.13.

In the transport sector, the DfT's TAG Unit A1.1 (DfT, 2018, p.4, emphasis added) includes more detailed guidance on when and how to incorporate residual values in appraisal:

2.3.5 The appraisal period should cover the period of use of an asset but assets may still have some value at the end of the appraisal period. ***Residual asset values should be included in CBA of projects with finite lives of fewer than 60 years. Residual values should be based on the resale or scrap value of assets****, including land and buildings; include any related clean-up costs; and account for 'residual value risk', the uncertainty around the future resale or scrap value. The Green Book provides guidance on valuing land and guidance should be sought from DfT or external risk experts on risk adjustments.*

2.3.6 ***Residual values should not be included for projects with indefinite lives with an appraisal period ending 60 years after scheme opening****. Where a special circumstance, such as a franchise, limits a project's life, the residual value should be estimated by:*

• estimating the 'unconstrained project benefits', the benefits disregarding the special circumstances, over the appropriate appraisal period (i.e. either the asset life or 60 years for an asset with an indefinite life); and

• subtracting the benefits from the project life dictated by the special circumstance from the unconstrained project benefits to give the residual value."

TAG Unit A1.1 can be interpreted to differ from the Green Book in two respects:

- For the case of projects with asset lives beyond 60 years, where it does not advise the inclusion of residual values. We note, however, that the recent Appraisal Periods Consultation states that "where a scheme involves large capital expenditure towards the end of the 60-year appraisal, residual value may be considered on a case-by-case basis subject to contacting the DfT for advice" (DfT, 2020, p.10).
- With regards to the calculation method, where it suggests a 'resale or scrap value' approach – the Green Book recognises the market value as only one part of a broader residual value which reflects the total opportunity cost of the asset at the end of the appraisal period.

The HS2 Full Business Case (DfT, 2020a) is a rare example of the use of residual values in transport infrastructure appraisal in the UK. This uses the Boardman et al. (2018) economic approach to calculate the BCR including Residual Value for operating years 61-100, for the purposes of a sensitivity test. Based on the numbers given, the Residual Value appears to be around £25bn (at 2010 Present Value[37]). The alternative approach, straight line depreciation from the construction cost implies an RV in the region of £2bn (at 2010 Present Value). This indicates the large potential differences, empirically, between the approaches.

In relation to financial appraisal, HM Treasury (2018) guidance on the Financial Case does not provide any explicit advice on calculation of RVs, and again the development of clear guidance would be useful.

[37] or £38bn if WEIs are included.

2.3 International Appraisal Practice

The table below summarises a rapid survey conducted by the authors in January 2021, of transport appraisal practice internationally (Table 3). This focused on three specific components and tried to answer the following set of questions:

1. **Appraisal Period**. What is the standard appraisal period for major transport projects?
2. **Modelling Period.** What is the standard modelling period and what is done to cover any difference between the modelling period and the appraisal period (extrapolation, growth cut offs, demand capping, etc.)?
3. **Residual Value**. Is any residual value or other method used to represent the value of the project beyond the standard appraisal period? If so, what is it and what elements of scheme costs and benefits are allowed to be represented in the RV?

In addition, we report the discount rates used for each case.

We are indebted to the following for their assistance with this survey:

- New Zealand – Ian Wallis
- Australia – Neil Douglas
- USA – Glen Weisbrod
- Netherlands – Niek Mouter [additional material provided by Pauline Wortelboer]
- Sweden – Jonas Eliasson.

Table 3: Transport appraisal practice internationally – appraisal period, residual values and discounting

	Netherlands	Sweden	US	Australia	New Zealand	European Commission
Appraisal period	Default 100 years (regarded as an approximation of an infinite period)	60 years for 'major infrastructure', with variation between 25 and 60 years depending on type of investment	Default 30 years, with variation between 14 and 50 years depending on project useful life (50-year for major structures such as bridges, rail lines and tunnels, as their useful life extends at least 50 years)	Recommended to be set at the expected life of the asset created (can typically vary between 10 and 50 years). Jurisdictions may set maximum appraisal period (e.g. 30 years)	Standard of 40 years. May use 60 years for long-lived infrastructure (or less than 40 for consistency with useful lifespan). Rationale: appraisal period sufficient to cover at least 90% of the PV of costs and benefits	25-30 years for transport projects, depending on type of investment (see table on p.42)
Residual value	Not included with the 100-year period.	No (in general), though sometimes used for a package of investments.	Yes, commonly applied. RV can apply to both assets with expected service lives longer than the analysis period, and shorter-lived assets that are assumed to be implemented late in the analysis period. The accepted practice is to apply straight-line depreciation of the original asset value over its useful service life. Residual value is then added to the numerator of the BCR	Yes, recommended where asset lives extend significantly beyond the end of the appraisal period. Where jurisdictions set maximum appraisal periods (e.g. 30 years) shorter than assets life, add RV to allow for net benefits beyond the end of the appraisal period (ATAP, 2018, p.16). Benefit-based methods recognised, but recommended approach is a straight-line depreciation of capital costs (as a whole or by components)	No specific procedures for treatment or valuation of any residual value.	"RV shall be determined by 'computing the net present value of cash flows in the remaining life years of the operation'.(...) Also, the depreciation formula should be used in the special case of projects with very long design lifetimes, (usually in the transport sector), whose residual value will be so large as to distort the analysis if calculated with the NPV method" (EC, 2014; p.44-45)
Residual value (exceptions)	Sometimes included if assumed life span and appraisal period is shorter (e.g. where technological and price developments are very uncertain, leading to uncertain long term effects too)	CBA for a package of investments with different lifespans: in that case a method is needed to calculate a kind of "weighted lifespan". In such cases (rare), the RV after n years of an investment with normal lifespan N and cost K is assumed to be K*(1-n/N) (straight-line depreciation)	N/A	N/A	N/A	Recommendations above for transport point out to a depreciation method, but the examples used in the guidance calculate all net benefits beyond appraisal period

Residual value components considered	N/A	Cost saving based on depreciation	Cost saving based on depreciation	Cost saving based on depreciation	N/A	Possibly all net benefits beyond appraisal period (e.g. see a road example in p.105 and a rail example in p.117)
Modelling Period	Reference year 2040 and extrapolation for the rest of the period	Recommended years are T1 = 2025 (start year), T2 = 2040 (1st forecast year), T3 = 2065 (2nd forecast year). All benefits are calculated at time T3. Benefits are assumed to grow at a rate proportional to traffic growth between T1 and T2, and at a (different) traffic growth in the period T2 to T3, and then no growth after T3	30-year modelling period	-	No specific procedures to address differences between standard appraisal and standard modelling periods	N/A
Discount rate	Until recently 2.5% (plus 3% risk premium). Currently heading towards 2%	3.50%	7%	7%	4% (recently reduced from 6%), with sensitivity tests at 6% and 3%	SDR of 5 % is used for major projects in Cohesion countries and 3 % for the other Member States; financial discount rate of 4%
Source (Appraisal guidance)		https://www.trafikverket.se/globalassets/dokument/for-dig-i-branschen/asek-kapitel-5-modelltillampning-o-kalkylvarden.pdf	https://www.transportation.gov/sites/dot.gov/files/2020-01/benefit-cost-analysis-guidance-2020_0.pdf	https://www.atap.gov.au/tools-techniques/index	https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual	https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

The survey shows variability across countries and regions, however:

- Appraisal periods are usually allowed to vary depending on type of investment (usually based on expected asset life);
- Appraisal periods for long-lived transport infrastructure are commonly capped at 50-60 years, although the Netherlands uses 100 years;
- Residual values are generally used, beyond the chosen appraisal period – except for the Netherlands and New Zealand (in the case of the Netherlands this is because the appraisal period is considered to be an approximation to infinite asset life and therefore is assumed to implicitly include any residual value as part of the modelled streams of costs and benefits);
- The most common residual value method is straight line depreciation, while the European Commission CBA guidelines also include the extrapolation of net benefits approach.

In addition to our survey, a HEATCO report (Odgaard et al, 2006) from over 15 years ago summarised the practice at the time in a broader set of European countries. Below we replicate their summary table, which indicates that 18 out of 24 countries allow for the inclusion of residual values, with a further 3 countries allowing full life-time of infinite appraisal periods (and thus not requiring residual value).

Table 4: Treatment of Terminal/Residual Value in 24 European countries, 2005

Technique	Number of countries	Countries
Include terminal/ residual value	18	North/West: Austria, Belgium, Denmark, Finland, France, Switzerland, UK East: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic, Slovenia South: Greece, Italy, Spain
Do not include terminal/ residual value	3	North/ West: Ireland South: Malta, Portugal
Do not include terminal/ residual value, because appraisal period equals lifetime or infinite	3	North/ West: Germany, Netherlands, Sweden

Source: Odgaard et al., (2006), Table 4.1, p27

The International Comparisons of Appraisal Practice study for DfT (Mackie and Worsley, 2013), did not gather evidence on the use of residual values, however it did cover appraisal periods, with Germany recorded as using “Component specific service lives and annuity factors”.

Of all sources of documentation reviewed, arguably the European guidance included the largest amount of detail given to the topic of Residual Values and methods. Therefore, the following sub-section provides a more detailed description of the European guidelines.

Last but not least, we should also mention the World Bank guidance (Mackie et al., 2005a,b) which is applicable globally, and is used primarily in low- and middle-income countries where the Bank invests. Since this includes a relatively concise and focused set of guidance around RV, we provide an extract of that section below.

USE OF RESIDUAL VALUES

Where a project is dominated by one long-lived asset – for example, the bridge described above – there may be some interest in knowing what the longer-term benefits are.

> **Residual value** is an item in the appraisal which captures net benefits beyond the formal appraisal period.

A residual value is calculated in exactly the same way as the NPV, except that the time period is from (T+1) to ω, where ω is the final year of the project's life.

$$\text{Residual value, R} = \sum_{t=T+1}^{\varpi} \frac{B_t - C_t}{(1+r)^t}$$

The residual value is a net value. It includes the residual stream of benefits **minus** the residual stream of operating and maintenance costs.

In reporting the results of the appraisal, the residual value should be reported **separately** from the NPV and IRR. The form is: "Residual Value in Years xx to yy = $nnn". An example is given in Table 2.

Table 2. Appraisal Results and Residual Value for a Bridge Project

Years	Costs, $M Present Value @10%	Benefits, $M Present Value @10%			Net benefit, $M Present Value @10%
		Passengers	Freight	TOTAL	
0-3	200	0	0	0	-200
4-39	4	44	239	283	279
40-79	1	1	5	6	5

Net Present Value = $79M
over 40 years @10%

Internal Rate of Return = 14%
over 40 years

Adjusted Internal Rate of Return = 12%
over 40 years

Residual Value (i.e. net benefit in years 40-80) = $5M

Note that the key parameters in this example are: discount rate (10%), horizon year (80 years) and appraisal period (40 years).

Some Pitfalls to Avoid

Project Creates a Mixed Set of Assets

A major transport infrastructure project usually includes the creation of a mixed set of assets, including earthworks, structures, pavement (or track) and equipment. In these cases, a judgement will be required about the most appropriate appraisal period.

If the appraisal period is set long – for example, 40 years – then some of these assets will require **replacement** when they reach the end of their useful life, **during** the appraisal period. The replacement costs must be included in the stream of future costs in the appraisal, in the year when they will be incurred.

It will often be clearer for the decision-maker, and not necessarily detrimental to the NPV, to set the appraisal period to match the asset life of an asset with an intermediate life. For example, for a road project, suppose the pavement has a useful life of 20 years before renewal is required. In this case, it may be appropriate to evaluate over 20 years, rather than extend to 25 years, during which time expensive renewal work will be necessary.

Appraisal Period Is Not Flexible

Where the appraisal period has been determined in advance, for example by the administrator of a particular investment programme as a whole, residual values have a useful role to play. In these cases, the NPV and IRR must be calculated over the stated appraisal period. However, a residual value – calculated as shown above – can be calculated and reported in order to indicate what the consequences of the restricted appraisal period were.

Source: Mackie et al., 2005b

The World Bank guidance therefore includes RV and seems, in principle, agreeable to an approach based on extrapolating net benefits beyond the appraisal period. However, this must also be interpreted carefully within their context of relatively high discount rates, which means that RV will often have a relatively modest impact.

European Guidance

There are two important sources of appraisal guidance that are used in practice in Europe – these are the EU CBA Guide (EC, 2014) and the European Investment Bank's RAILPAG (EIB & EC, 2005). The EU CBA Guide states:

> "A residual value of the fixed investments must be included within the investment costs account[ed] for the end-year. The residual value reflects the capacity of the remaining service potential of fixed assets whose economic life is not yet completely exhausted[38]. The latter will be zero or negligible if a time horizon equal to the economic lifetime of the asset has been selected.
>
> According to Article 18 (Residual value of the investment) of Commission Delegated Regulation (EU) No 480/2014, for project assets with economic lifetimes in excess of reference period, their residual value shall be determined by 'computing the net present value of cash flows in the remaining life years of the operation'.[39] Other residual value calculation methods may be used in duly justified circumstances. For instance, in the case

[38] "Where relevant, this potential should also account for the value of increased resilience to climate change, for example in the case of development of a harbour and industrial area in a coastal area that may be at risk from sea-level rise in the longer term".

[39] "In this regard, it is suggested that revenues and costs are assumed constant after the end of the time horizon, unless demand analysis is carried out over a longer period and provides differently".

of non-revenue generating projects[40], by computing the value of all assets and liabilities based on a standard accounting depreciation formula[41] or considering the residual market value of the fixed asset as if it were to be sold at the end of the time horizon. Also, the depreciation formula should be used in the special case of projects with very long design lifetimes, (usually in the transport sector), whose residual value will be so large as to distort the analysis if calculated with the net present value method.

The residual value can be singled out either within the project inflows or within the investment costs but with negative sign (see table [5] for an example)".

Table 5: EU CBA Guide Example: Total investment costs, €000s

		Years						
	Total	**1**	**2**	**3**	**4-9**	**10**	**11-29**	**30**
Start-up and technical costs		6,980		1,816				
Land		1,485	757					
Buildings			37,342	17,801				
Equipment			11,355	23,273				
Machinery			25,722					
Initial Investment	**126,531**	**8,465**	**75,176**	**42,890**				
Replacement costs						11,890	9,760	
Residual value								-4,265
Total Investment costs	**152,655**	**8,465**	**75,176**	**42,890**		**11,890**	**9,760**	**-4,265**

These can include also costs, e.g. for feasibility studies, borne before the start of the evaluation period, although not eligible for EU funding.

In the example, expenditures of EUR 11.9 and 9.8 million are expected in year 10 and 20, respectively, to replace short life equipment and machinery.

The residual value is considered with negative sign because it is an inflow.

Source: EC (2015), Table 2.3

The Financial IRR and Financial NPV/K are calculated using the Residual Value as part of the financial inflows, i.e. as negative project costs. In the Financial Sustainability analysis the "residual value should not be taken into account unless the asset is actually liquidated in the last year of the analysis". In Financial Analysis of PPPs, the Residual Value is usually excluded because "in many PPP contracts the infrastructure is returned to the public sector at the end of the period".

In the Economic Analysis, "the shadow price of the project's residual value must be estimated. This may be done in two mutually exclusive ways:

- by computing the present value of economic benefits, net of economic costs, in the remaining life-years of the project. This approach shall be adopted when the residual value is calculated in the financial analysis with the net present value of future cash flows method [see above];

[40] "These are defined as projects that: (i) generate no revenues at all, (ii) generate revenues which are consistently lower than operating costs during the whole reference period or (iii) generate revenues which may exceed operating costs in the last years of the reference period but whose discounted net revenues are negative over the reference period".

[41] "In this case, any asset replacement costs computed during the reference period must be included in the calculation, even if these are regarded as O&M costs for the purpose of the calculation of the discounted net revenue to determine the Union assistance".

- by applying an ad hoc conversion factor to its financial price. This is calculated as an average of the CFs of the single cost components, weighted by the relative share of each component in the total investment. This approach shall be adopted when the depreciation formula has been used in the financial analysis.

A Conversion Factor of 0.97 is used in the example, and the Residual Value is treated as a negative cost in year 30. "The analysis is performed using a 30-year reference period which is common for road projects. A residual value of the investment is considered at the end of the reference period; the residual value is EUR 13 million in the financial analysis which is calculated on the basis of the net present value of cash flows generated after the reference period (based on the perpetuity formula) and EUR 150 million in the economic analysis (based on the depreciation formula and corrected by the conversion factor)".

As in the Financial Analysis, the RV is included as a negative Cost in the economic analysis, according to the EU CBA Guide (2014).

An Urban Transport case study "does not generate net revenues (operating costs higher than operating revenues). The residual value of the investment is hence calculated based on the net book accounting method. The depreciation rates of the various investment components (taking into account the replacements) are" as follows (Table 6). Note that depreciation is not straight line but geometric in this case[42].

Table 6: Depreciation rates for investment components (tram mode) in EU CBA Guide (2014)

Investment Component	Depreciation rate
Tram Infrastructure	3.5%
Tram rolling stock	5.5%
TMS	13%

The other important EU-based source is RAILPAG (EIB & EC, 2005), which states:

"In rail projects, the main elements of an investment project are: the infrastructure of the line, the track superstructure (which includes electrification and signalling systems) and the rolling stock. The useful life of the various components can be quite different and, for some of them, very long. Annex B[43] includes a list of the useful life of specific railway components. Since only one appraisal period is used for a given CBA calculation, specific attention must be given in rail projects to consistent assumptions on renewals and residual values of the various elements. In fact, the result of an economic appraisal should not depend on the length of the appraisal period selected for the analysis, provided it is long enough to capture the stabilisation of traffic growth under the scenario considered. Regarding infrastructure, the minimal Operating Period is established according to the potential loss of functionality or safety of the element. The residual value of the assets produced by the investment at the end of the Operating Period depends on the remaining functionality of the project components. This is difficult to estimate because it will depend on technological obsolescence, on the potential alternatives to the project at the time and the cost of its eventual disposal. The theoretical residual value is obtained from an

[42] RAILPAG notes that "The depreciation formula is usually linear with time, but in many cases convex functions, notably for rolling stock, are used" (EIB & EC, 2005).
[43] Annex B is copied as an Appendix to this report.

assumption about the most efficient use of the assets after the Operating Period. It will usually be positive if the rolling stock can still run without major problems and the infrastructure and superstructure are still operational. It could also be negative, for instance if the best option is to dispose of the assets and this involves important expenditure (for instance, in re-landscaping).

Residual values are ideally valued as the discounted values of the costs and benefits in an indefinite time series. In this case, the impact of the length of the Operating Period is nil. The residual value is often calculated, however, as the non-depreciated part of the asset. To assume a depreciation method based on the replacement value means accepting that present market conditions will remain stable and that a "replaced" project will be, after its Operation Period as competitive as it is today. This is linked to adequate maintenance and some minor upgrading expenditure to maintain the project at adequate standards. Under these circumstances a rather high residual value could be acceptable.

Another option is to simply adopt a depreciation formula defining the residual value at any given year. The Operating Period should be shorter than the depreciation period of the main asset of the project (i.e. the infrastructure, for major projects). The depreciation formula is usually linear with time, but in many cases convex functions, notably for rolling stock, are used.

A particular component requiring attention is the land purchased for the project. This component, at the end of its useful life, will probably keep its present value (in constant terms) or even increase it. In general a value between the present value in current and in constant terms would be used. Some research is needed to establish residual values for linear rights-of-way and for more adaptable plots such as those used for stations and facilities[44]. In summary, CBA calculations in the rail sector need to take into account the useful life spans of various assets. When structuring an appraisal, care should be taken to make a set of assumptions on renewals and residual values that is consistent with the appraisal period selected for the analysis. It is often convenient to place the end of the appraisal period at the end of the useful life of a major component of the investment".

2.4 Other Sectors in UK Government

The table below summarises a further rapid survey conducted in January 2021, of appraisal practice across Whitehall (Table 7). Responses were received from Department for Education (DfE), Ministry of Defence (MoD), Business Energy Innovation and Skills (BEIS) and Department for Environment, Food and Rural Affairs (Defra), and the authors are indebted to the following for their assistance:

- Colin Smith, Sara MacLennan, Jose Poncela and Joshua Gifford, Defra
- Luke Heley, MoD
- Ingrid Pechinger, BEIS
- Alan Little, DfE

[44] "The high value of some urban land owned by railways signals the interest of the proposed research."

Table 7: Appraisal practice in other sectors (UK)

	Department for Education	Ministry of Defence	BEIS	DEFRA
	Education	Defence	Business, Energy and Industry	Environment
Appraisal period (standard)	DfE follows the central HMT Green Book guidance (no supplementary guidance)	25 years for a building (assumed economic life, the point at which a significant upgrade is required to keep it functioning)	10 years	Case by case basis, with a steer to longer periods (including above 100 years)
Are longer appraisal periods allowed?		Appraisal periods can be extended (e.g. to 40 years), but there is an issue with getting realistic forecasts over such a long period of time. If results of appraisal could be sensitive to time horizon then impact should be understood with sensitivity analysis	Longer appraisal periods are allowed where the evidence suggest that using the standard 10 years would not be fit for purpose.	For ecosystem services: the UK Natural Capital Accounts project future service flows over 100 years, so as to reflect the longevity of renewable natural assets. For flood schemes: case by case basis, as expected asset life usually exceeds 100 years. Longest lived assets sets length of period.
Residual value		Yes, "if the life of the main asset is longer than the appraisal period required, a residual value can be assumed at the end of the project's life (see paragraphs 19, 24, and 44) and shown as an inflow at that point in time, as long as the capability or service being provided by the asset is likely to be required beyond the appraisal period" (MoD, p.45)	Typically, no RV method used	For flood schemes: decommissioning cost at the end of appraisal period (i.e. this is a negative RV)
Residual value components considered		All components, including the best estimate of the value beyond appraisal period, any additional 'scrap value' and any negative value such as liabilities or remediation costs. Guidance includes RV recommendation by asset type (e.g. land, buildings and equipment).	N/A	Decommissioning costs (appraisal period set to longest asset life, so all benefits and costs covered within appraisal period)
Source (Appraisal guidance)		https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/275550/JSP507_Part_2_U.pdf	BEIS follows the central HMT Green Book guidance (no supplementary guidance)	https://www.gov.uk/government/publications/enabling-a-natural-capital-approach-enca-guidance

This revealed a mixed picture across sectors outside transport, including the use of varying RV approaches depending on the context and also cases where RV is not typically used. RV methods are used by MoD and Defra. In the case of MoD for assets within the 60 year range (since typical appraisal periods are between 25 and 40 years) and in principle could include any relevant costs and benefits beyond the appraisal period. In the case of Defra, RV is used for long term decommissioning costs of flood schemes, even for schemes appraised over a 100-year appraisal period. Such RVs will be negative.

Reflecting upon both parts of the review (transport internationally and across sectors), the conclusion is that accounting for RV is a relatively familiar practice, although its use is uneven. The prominence of RV is also linked to the appraisal period. Where appraisal periods are shorter relative to asset life, the scope for substantial RV increases, and this is recognised in cases where a 'net benefits extrapolation' approach is considered (including European CBA guidance, and also the World Bank and the case of the Ministry of Defence in GB). On the other hand, where there is allowance for a very long appraisal period (at least 100 years) there is less scope for residual value to be a significant part of the appraisal. This is the case for transport appraisal guidance in the Netherlands.

2.5 Review – Main Findings

In conclusion, the main findings on residual value methods and appraisal period from the literature are:

- The principle of residual values is widely accepted. There is no unique, agreed method for calculating residual values, however, and there is a lack of consistency between theory and practice. Hence there is an opportunity to provide new guidance.
- In practice, there is some use of economic NPV methods (extending net benefits beyond the appraisal period) and some use of depreciation methods – in Europe and also in the UK.
- The depreciation method does not capture the stream of net benefits after the appraisal period, instead it provides a proxy for this. The HS2 case suggests the difference might be large, empirically, nevertheless the straight line depreciation method is the most promising of the accounting/financial methods because of its ease of calculation – even if it has to be recognised as an underestimate or 'lower bound' estimate of the true economic RV.
- The length of the appraisal period (relative to asset life) is directly linked to the relevance of RV, meaning that when appraisal period is set to cover more of the asset life of assets, then the role for RV diminishes (e.g. the Netherlands).
- When using residual values in social value for money calculations (rather than in the Financial Case), including the full range of net benefits is likely to make a large difference, and this is only feasible using the economic approach set out in the literature.

3. Conceptual Framework, Evidence & Applications

In this section, we give a synthesis of the concepts and theory emerging from the literature review. To ensure applicability in practice, we do this within the context of the existing theoretical framework of UK transport CBA. We include relevant evidence where it is available, and discuss applications to transport appraisal.

3.1 CBA and Maximising Public Value over the Long Term

The UK transport CBA framework is set out in TAG Unit A1.1 (DfT, 2018). The overall CBA metrics used in the UK are the Benefit:Cost Ratio (BCR), Net Present Value (NPV) and NPV/capital cost (NPV/k). The rationale for the widespread use of BCR is that in public sector decision-making, the constrained resource is the Broad Transport Budget. Public value can be maximised by choosing interventions carefully in light of their BCR and NPV – the use of BCR and NPV in the decision process is described in the Value for Money Framework (DfT, 2017a,b).

NPV is the absolute measure of public value created by the scheme, over the long term. TAG measures the appraisal period in years, and the NPV is given by:

$$NPV = \sum_{y=oy}^{k} \frac{B_y}{\prod_{i=base}^{y}(1+r_i)} - \sum_{y=sy}^{k} \frac{C_y}{\prod_{i=base}^{y}(1+r_i)} \quad (6)$$

where

NPV is the project's Net Present Value;

y is the year (e.g. 2021);

i is a separate year index starting from the discounting base year, 2010, to the year *y*;

sy is the start year for project costs;

oy is the opening year of the project, when benefits begin;

k is the last year of the appraisal period;

By and *Cy* are the benefits and costs (as defined in TAG) in year *y*;

r_i is the social discount rate in year *i*.

Key points in time are therefore: the discounting base year (2010); the project start year, *sy*, which is also the start of the appraisal period; the opening year, *oy*, and the final year of the appraisal period, *k.*

If we add the residual value at year *k* into the formula, we obtain:

$$NPV = \sum_{y=oy}^{k} \frac{B_y}{\prod_{i=base}^{y}(1+r_i)} - \sum_{y=sy}^{k} \frac{C_y}{\prod_{i=base}^{y}(1+r_i)} + \frac{H_k}{\prod_{i=base}^{k}(1+r_i)} \quad (7)$$

and if the Boardman et al. (2018)/Freeman (2014)/Lowe (2008) economic approach is taken, then we can rewrite the last term as follows:

$$NPV = \sum_{y=oy}^{k} \frac{B_y}{\prod_{i=base}^{y}(1+r_i)} - \sum_{y=sy}^{k} \frac{C_y}{\prod_{i=base}^{y}(1+r_i)} + \sum_{y=k+1}^{F} \frac{(B_y - C_y)}{\prod_{i=base}^{y}(1+r_i)} \quad (8)$$

where

F is the last year of the useful asset life; and

years *k+1* to *F* constitute the residual value period.

To calculate the BCR, all the benefit terms (involving B_y) in equation (8) would be collected, and divided by the cost terms (involving C_y). Therefore the RV is not simply added to the PVB or deducted from the PVC, but may affect both.

In summary, the economic approach to RVs is an extension of the existing TAG approach to NPV and BCR, and can be formalised as above.

3.2 Assets and Flows

Transport assets provide a flow of services, for example a road provides its users with ease of access to a range of destinations by various modes. In economic appraisal, the value of this stream of services is measured using the change in consumer surplus between two scenarios, with the road versus without the road. The user benefit approach is set out in TAG Unit A1.3 (DfT, 2017c) and the value of non-marketed aspects of the journey[45] are included using non-market valuation techniques. The net benefits are aggregated over the whole appraisal period using the approach set out above (equation 6).

A closely-related approach can be taken to the valuation of assets from a financial perspective (Damodaran, 2014). The asset value can be calculated using a discounted cash flow calculation, where the expected cash flows in each year are discounted at a rate which reflects the *weighted average cost of capital (WACC)* – including both debt and equity – in that use:

$$Value\ of\ Asset = NPV = \sum_{i=0}^{F} \frac{E(Cash\ Flow_i)}{(1+WACC_i)} \quad (9)$$

The WACC takes into account the risk associated with that particular type of investment, whereas the social discount rate *r* in (6) is a risk-free rate with an allowance only for catastrophic risk[46]. Examples of the WACC for different sectors are shown in Table 8. Transport infrastructure is not itemised, however other sources indicate that transport infrastructure assets are typically seen and valued as a relatively stable, low risk, 'utility'-type investments[47]. In the Capital Asset Pricing Model (CAPM), the cost of capital is made up of the risk-free rate, which may currently be as low as 0.5% for UK Government 10 Year Gilts, plus a sector-specific (and potentially project-specific) risk premium.

Table 8: Weighted Average Cost of Capital by Sector, 2019/20

Sector	*WACC, % per annum*
Technology	7.7%
Automotive	7.4%
Media & Telecommunications	6.0%
Energy & Natural Resources	5.3%
Real Estate	5.0%

Note: WACC is shown *after* corporate taxes. Source: KPMG (2020), *Cost of Capital Study.* Data is derived from German, Austrian and Swiss markets.

[45] e.g. non-working time and journey quality

[46] This approach is consistent with Lind (1982), who argues that the correct way to deal with risk in public choice is through project-level risk analysis and reporting rather than through an adjustment to the discount rate (essentially the approach that HM Treasury and DfT now adopt).

[47] E.g. analysis by CEPA (2017) for the National Infrastructure Commission showed that the yield on UK Infrastructure Bonds varied between 3.0% and 6.5% over the period 2006-2016. Sarmento and Oliveira (2018) found an average WACC of 6.8% for a set of Portuguese highway projects started between 1999-2010.

Another useful comparator is the concept of natural capital (Costanza et al., 1997). One important way of valuing natural capital assets is to measure the flows of ecosystem services deriving from them, and to calculate the Net Present Value of those flows over the long term (Freeman et al., 2014) – using non-market valuation methods to value the ecosystem services and capture the Total Economic Value (TEV). Again, this is analogous to the approach used in transport appraisal (equation 6), but with a slightly different scope: there tends to be more focus on non-use values such as existence and bequest values[48], and option values also play a key role.

In all three cases above, it is possible to value the asset by calculating the NPV of the stream of services it provides.

In a financial context, the above would be considered 'income-based approaches' to asset valuation. There are other ways of valuing assets, and the alternative approaches are:

- market-based approaches – see 2.1 above;
- cost-based approaches, whether based on deprecation from initial costs, or replacement cost methods (such as a Modern Equivalent Asset Value)[49].

However, those methods suffer from the limitations that:

- cost-based approaches do not necessarily reflect the value generated for users or the wider population;
- they generally exclude the value of non-marketed services, which are key to many natural capital assets and also to transport assets – in a transport context the omitted items will include social, environmental and wider economic impacts (including user benefits not captured in revenue).

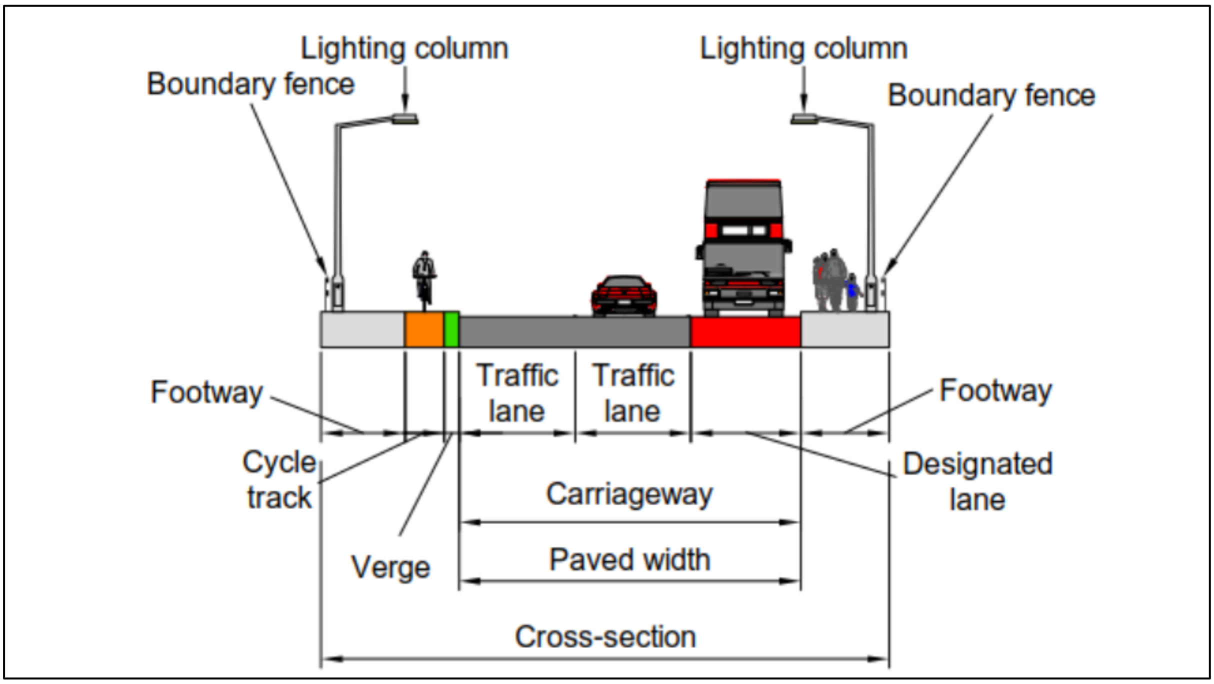
3.3 Transport Infrastructure Assets

In order to make progress with the use of residual value in transport appraisal, we next consider the composition of transport assets. This is only a brief introduction and the subject would benefit from a more comprehensive mode-by-mode treatment.

As shown in the cross-sectional diagrams below (Figures 1, 2 and 3), a road consists of many components above and below ground. Figure 1a highlights how the available width of an urban road can be allocated to different users, with implications for wear and tear, maintenance, surfacing, segregation, kerbs and markings. Figure 2 also shows road signs including variable message signs (VMS) – part of the technology component of highways – and also illustrates the grading of the land (earthworks). Figure 3 shows the main components below ground.

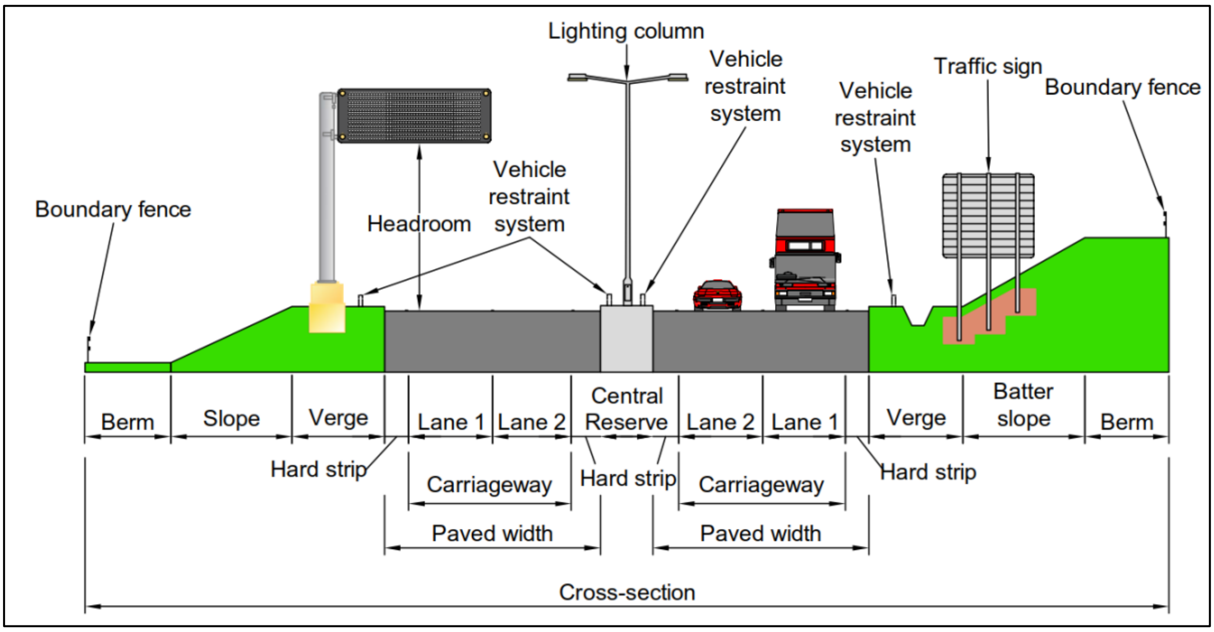
[48] Although these were considered in the A303 Stonehenge tunnel valuations, for example.
[49] e.g. RICS (2018)

Figure 1: Example road components (above ground) – urban single carriageway



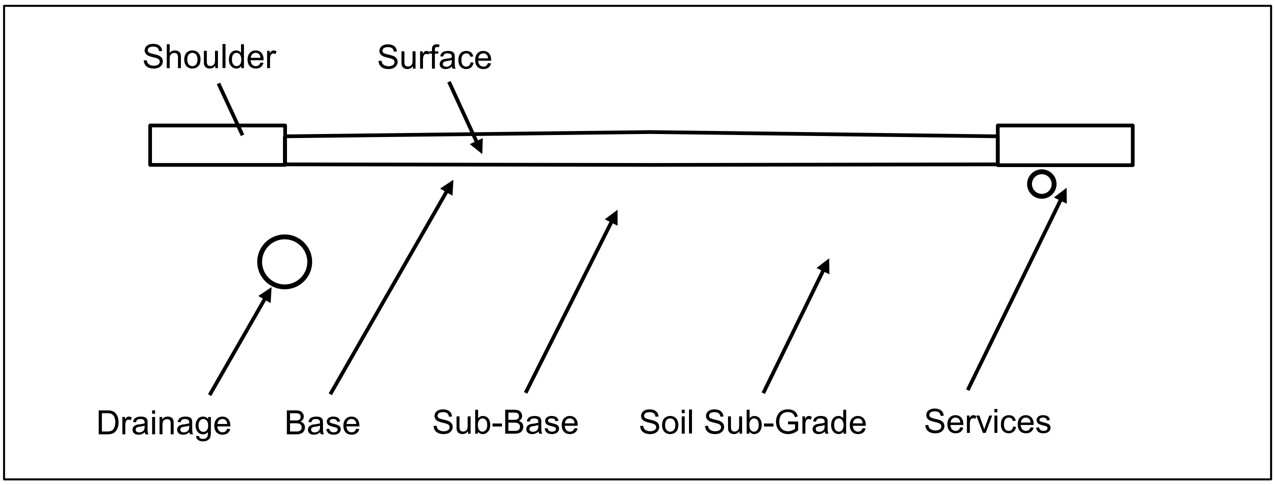
Source: Highways England (2020), *CD127 Cross-sections and headrooms*

Figure 2: Example road components (above ground) – rural dual carriageway



Source: Highways England (2020), *CD127 Cross-sections and headrooms*

Figure 3: Example road components – surface and below ground



Not shown specifically in the above are:

- land – purchased for use as transport infrastructure;
- earthworks – necessary to create a suitably-graded right of way, including embankments and cuttings;
- structures – such as bridges, tunnels and retaining walls;
- junctions and the associated traffic signals and other components;
- buildings – such as control centres and stores;
- equipment – for operations and maintenance purposes.

It is the combination of all these asset components that provides the mix of services offered by the road. Equation (8) could be rewritten with a mode subscript, *m*, to show that the benefits must be summed across modes (cars, buses, freight vehicles, pedestrians, cyclists, etc.):

$$NPV = \sum_{m,y=oy}^{k} \frac{B_{m,y}}{\prod_{i=base}^{y}(1+r_i)} - \sum_{y=sy}^{k} \frac{C_y}{\prod_{i=base}^{y}(1+r_i)} + \sum_{m,k+1}^{F} \frac{(B_{m,y})}{\prod_{i=base}^{y}(1+r_i)} + \sum_{k+1}^{F} \frac{(C_y)}{\prod_{i=base}^{y}(1+r_i)} \tag{10}$$

Many of the costs will be common costs across modes (e.g. earthworks, lighting), while some may be specific (e.g. surfacing per lane). Equation (10) could be modified to reflect this cost structure more accurately – for example if the purpose was to optimise the design of the road to match benefits to costs – however for the purpose of thinking about RVs this is not essential.

3.4 Asset Lives across Modes, by Component

Central to RVs is an understanding of asset lives. The following table gives a synthesis of evidence on asset lives from: the UNITE UK accounts (Tweddle et al., 2002); the World Bank guidance on projects with a very long life (Mackie et al., 2005b); and additional recent evidence from DMRB and elsewhere, which is itemised below the Table.

Table 9: Average life expectancies of asset types for the UK (years)

Asset type	**Roads**	**Railways**	**Footways & Cycleways**	**Air**	**Maritime**
Earthworks	100				Up to 50
Bridges/tunnels	Up to 100				
Foundation	40 *		40 **	100 ***	
Surface	10		20 ****	10-15 ***	
Track		14 to 40			
Electrification		30 to 40			
Signalling		10 to 50			
Telecomms		7 to 40			
Buildings	50	30-40		20 to 60 ***	Up to 50
Equipment	12			4 to 20 ***	2 to 30

Note: data relates to asset lives in the UK where possible. Based on the UNITE Transport Account for the UK, Tweddle et al (2002), and World Bank Transport Note TRN-18: Projects with a Very Long Life (Mackie et al., 2005). Source for: *Roads foundation life: Highways England (2020), *DMRB CD 226 Design for new pavement construction*. **Footways & Cycleways foundation life: Highways England (2020), *DMRB CD 239 Footway and cycleway pavement design*; ***Heathrow Airport Ltd (2019, p124); ****Atkinson et al. (2006) for footway/cycleway resurfacing – less frequent than for Roads due to reduced loading and traffic volumes.

Among the key points here are that:

- there is some consistency across modes, in that earthworks can often be treated as having a 100 year (or longer) useful economic life, and structures such as bridges and tunnels often have useful lives up to 100 years (in practice maybe 80-100 is typical[50]);
- foundation/sub-base components usually have a shorter lifespan, around 40 years (the airport number is an outlier here but may be due to different construction for airport runways versus roads or railways);
- rail clearly has a set of specialist components that differ from other modes, however these are well understood and asset life evidence exists from sources in the UK and internationally;
- walk and cycle facilities' asset lives are documented and can be analysed in a comparable way with other road assets;
- there are wide range of different asset lives among the components of transport infrastructure and so the CBA will need to include the replacement/renewal costs of each of them, in order to calculate the cost components during the RV period. This is simply an extension of what is already done during the appraisal period for transport infrastructure, however.

[50] e.g. see Appendix A: RAILPAG railway asset lives

An appraiser who is in contact with the engineering team responsible for a project should be able to obtain tailored estimates of life expectancies of components in that particular project. The generic evidence available from Highways England, other infrastructure managers and the literature (such as that summarised in Table 9) would also provide useful guidance. Overall, we do not see knowledge of approximate useful asset lives as a barrier to implementation of RVs beyond 60 years in the UK.

There is an interesting issue, though, around whether some assets should be treated as having an infinite or perpetual life, and what the implications of that would be for CBA. For example, Highways England (2020) Financial Statements state that: "All parts of the SRN are depreciated, apart from **land and the substructure of the road**, which are deemed to have an **unlimited useful life**". The land and substructure together make up 82.5% of the value (at gross replacement cost) for the roads component of the SRN – i.e. excluding structures, buildings, technology, etc. The remaining 17.5% by value is made up of: Surface layer; Drainage; Road marking and studs; Rigid concrete roads. Those items are depreciated in line with renewal costs and any condition depreciation.

This prompted us to look at the cost structure of HS2, and based on available evidence[51] we found that 56% of the capital costs (by value) were in the very long-lived categories of: Purchase of Land, minerals and permanent rights; Earthworks; Tunnels; Bridges and other structures. A further 28% were in the (arguably) rail-specific categories of: Stations, depots and buildings; and Electrical and other equipment. This implied that around 77% of the remaining ('non-rail-specific') capital costs were very long-lived.

This chimes with the observations about land in Section 2.3 above (from RAILPAG), and with the following paragraph in TAG: "2.3.2 For many transport investments, including most road, rail and airports infrastructure, it is expected that maintenance and renewal will take place when required. This effectively means that the asset life will be indefinite, or at least as long as maintenance and renewal activity is continued".

In order to avoid getting locked in to an assumption that all infrastructure assets will be maintained (or replaced) indefinitely, we need to give attention to *options* and *uncertainty* (see below, Section 3.6) – including the possibility that transport infrastructure built this decade will *not* be in sufficient demand to keep it open indefinitely.

In conclusion, asset life is important for at least two purposes in transport CBA generally:

a) For setting the appraisal period, which in theory should be based on the life of the longest-lived asset, and in practice has been capped at 60 years after opening;

b) For setting up the 'roll-over' pattern, for project components which have a shorter asset life and therefore require renewal during the appraisal period.

In the context of RVs and projects with a very long life, asset life is also important:

c) For setting the length of the RV period – the evidence in Table 9 might suggest 61-100 years after opening as a typical RV period across modes for infrastructure;

d) For setting the roll-over pattern during the RV period;

[51] e.g. DfT (2020a); HS2 Ltd. (2017); DfT (2013); HS2 Ltd. (2012)

e) For calculating the RV, if straight line depreciation methods are being used, which require knowledge of the asset life in order to interpolate to the value at the end of the appraisal period;

f) For implementing any 'component' approach to RVs, where we need to apply the RV calculation to only part of the total assets.

3.5 Comparability across Projects & Modes

The UK uses the benefit:cost ratio (BCR) to compare different investments in terms of value for money, the scarce resource being the Broad Transport Budget (DfT, 2018). Other interventions which do not fit the usual investment model, for example because they have a positive impact on the Broad Transport Budget (e.g. road pricing schemes) are addressed by the Value for Money Framework process (DfT, 2017a,b).

An important question is whether a long-lived transport project (e.g. 100 years from opening including 40 years' RV period) can be compared with one with a 60 year or 30 year life using these usual techniques. Boardman et al. (2018, p143-4) set out what we think is the theoretically correct position – that in fact an additional step is needed. They recommend two alternative approaches:

i. use the 'roll-over method', to repeat the shorter-lived project so that the lifetimes can be compared, e.g. 30+30 years compared with 60 years – the difficulty with this in the 60 years vs 100 years case is that there will some be residual value after 100 years, and we have not yet established whether there is a case for counting that (i.e. for looking beyond 100 years – indeed that would probably arouse greater concern than the 100 year horizon from the perspective of uncertainty);
ii. calculate the Equivalent Annual Net Benefits (EANB), which is the NPV (including RV one is justified) divided by the annuity factor (the sum of the discount factors over the life of the project) and use this to compare projects.

The problem with the latter in the UK context is that it does not express value for money, only an absolute annual NPV. It seems to us that it is rather difficult to have a metric which is both: a value for money metric and a value per annum metric.

Considering this further, the main reason why the usual DfT BCR approach would be inaccurate is if the BCR for the repeated project was significantly different from the BCR the first time the project was implemented. For example, this may be due to demand growth differing from cost growth over the long term, or due to the tapered discount rate profile (going down to 3.0% and then 2.5%) having a material impact on the balance between discounted costs and discounted benefits.

If this seems abstract, then consider the replacement of a ferry service with a fixed link, such as the Skye Bridge. If the bridge has an expected asset life twice as long as a replacement ferry, then the obvious approach in CBA would be compare the bridge scenario with a scenario where two replacement ferries are purchased and operated, one at the start of the appraisal period, and the other halfway through it. In other words, the 'roll-over method' above would be applied. In that case, the BCR for both options could be calculated (relative to doing nothing) or the bridge could be compared with the ferry replacement as the 'do-minimum'. Thus the decision-maker's information needs would be satisfied in relation to value for money. In this case, the demand forecasts – and their extrapolation over the long term – would need to be addressed for the bridge, and doing so would probably ease the task of projecting forward the demand for the second replacement ferry.

Across the Broad Transport Budget portfolio as a whole, there is a mix of shorter-term expenditure (e.g. revenue support, or new buses) and long term investment. It would certainly be worthwhile DfT considering whether applying BCR across these different categories creates any bias in expenditure decisions. Our instinct is that the discount rate is designed to take care of social time preference (between different profiles of benefits or costs over time) – then for the use of BCR across the portfolio to be biased, it would need to be due to some substantial divergence between the future BCR and the shorter-term BCR for certain repeated expenditures (shorter term expenditures).

A more obvious concern might be whether road and rail projects are being compared fairly, or whether active mode investment is being compared fairly with motorised modes under current guidance. Based on the evidence on asset lives above (Table 9), some asset types (e.g. earthworks, bridges/tunnels and foundations) that are needed for different modes (e.g. roads, railways and footways/cycleways) tend to have the same average life expectancy regardless of the mode they are used for. However, current appraisal guidance in the UK for walk and cycle schemes recommends the use of a much shorter appraisal period. Based on the evidence collected for this project, we believe there should be a high degree of comparability for infrastructure projects across modes which should in turn be reflected via comparable appraisal periods – the evidence does not support shorter asset lives for walking and cycling projects, or for rail, for example.

3.6 Rights of Way

It is worth thinking further about what it is that creates the value in a transport project. It is not only the infrastructure assets but the *rights of way* which provide accessibility – so we need to think about the durability of those rights of way over the longer term.

For example, consider:

i. a new bridleway[52] joining two towns through the countryside, where such as link is lacking;
ii. a new pedestrian crossing on a busy main road;
iii. a new estuary crossing, such as the proposed Lower Thames Crossing.

The first of these might require relatively modest infrastructure spending – the value comes from the connectivity, perhaps from a mix of recreational, commuting and other non-work purposes. Once it is created, it is likely to be maintained as long as there is demand for it. Unless it is badly planned, or there is an unforeseen downturn in walking and cycling, the right of way created will, in effect, be perpetual. As with any new provision, there is a judgement to be made about the length of the planning horizon (in the Netherlands, essentially 100 years), but there is no reason to consider the useful economic life of the project as being less than that of a new railway or road – it is simply that the assets are cheaper and used in a different way (possibly less intensively).

The second is another case in point. Although the crossing assets may consist of a set of signals and adjustments to the street furniture and road markings, the most valuable element

[52] footpath and cycleway

(to the users) is the right of way across the main road at this point. Again, if well planned there is no reason to think this crossing will be removed within the planning horizon – even if the signals, markings, etc., are replaced.

The third case is different in that it is very capital intensive, but it has in common with the second case (and the first) that if it is built, then as long as the demand is judged sufficient to justify the maintenance & renewals it will likely remain open.

Having focused on factors in favour of a common appraisal period across certain project types, it is also worth thinking about what makes some types of investment potentially more useful than others in the long term, and in the next section we discuss this under the heading of 'uncertainty and options'.

3.7 Uncertainty and Options

Uncertainty

Uncertainty is a part of the reality of long term planning. DfT has done a great deal of work recently on a draft 'uncertainty toolkit', designed to address the necessary changes in response to Covid-19 but also wider uncertainties, building on the existing TAG Unit M4 Forecasting and Uncertainty (DfT, 2019a) and the guidance on risk in TAG Unit A1.2 Scheme Costs (DfT, 2017d). When the uncertainty toolkit and the accompanying 'common analytical scenarios' are completed, it will be important to explore how they influence and integrate with long term benefits and costs in appraisal.

Under risk and uncertainty, the appraisal period is limited not only by asset life but also by the time period over which demand can be foreseen. If there is no expectation of future demand, then extending the business case further into the future is meaningless[53]. As discussed in the previous section, there are good reasons for believing that well-planned transport infrastructure and network improvements will indeed have a very long useful life. There are of course threats to this, including: technological shifts; social changes; and climate change. These factors are an integral part of the uncertainty toolkit and many other future planning exercises worldwide. We do not plan to go into uncertainty in depth in this paper, however:

- costs of major projects should be risk adjusted (TAG Unit A1.2) following a quantitative risk analysis (QRA) and consideration of optimism bias;
- risks around long term cost inflation are not necessarily well covered by standard QRA and should be considered in the light of the uncertainty toolkit and scenarios[54];
- future demand is also uncertain – common analytical scenarios are expected to deal with part of this, and project-specific or local strategy-level analysis the rest;
- values of benefits are uncertain – e.g. the recommended sensitivity tests around values of travel time savings (TAG Unit A1.3, p9) and high/low values of carbon reduction (TAG Data Book, Table A3.4);
- there is no getting away from the need to integrate the appraisal period, RV approach and risk and uncertainty in appraisal.

Options

[53] unless of course to capture decommissioning costs, as in the nuclear industry or the Defra flood management CBA.

[54] e.g. scenario assumptions around long term GDP growth, labour supply, energy prices and other relevant resource constraints.

In a world of uncertainty, it is also valuable to have (or to create) transport assets that open up *options* for us to respond flexibly to future changes. Conversely, it is risky to invest in assets which have few uses and are costly or impossible to adapt. The following paragraphs briefly consider 3 cases:

- options to re-use;
- options to decommission;
- options to defer.

Options to re-use

Table 10 gives a few select examples of the socially profitable re-use of transport assets initially designed for another purpose.

Table 10: Select examples of transport assets re-used, 1971 to date

Original Use	*Re-Use*
Ashbourne-Buxton Railway, Derbyshire	Tissington Trail (cycle/bridleway/trail) – intensive recreational use, SUSTRANS Route 68 (1971)
Bakewell-Buxton Railway, Derbyshire	Monsal Trail (cycle/bridleway/trail) – intensive recreational use, SUSTRANS Route 680 (1981)
Wadebridge-Padstow Railway, Cornwall	Cycle trail/bridleway – SUSTRANS Route 32 (1983)
Christs Hospital-Cranleigh-Shalford Railway, Surrey	Downs Link (bridleway) – SUSTRANS Route 223 (1984)
Old Selby-York Railway (replaced by new East Coast Main Line, 1983), North Yorkshire	Partly used to provide bypasses of the towns of Riccall and Barlby on the A19 road (1987); Partly used for SUSTRANS Route 65 Riccall-York (1987)
Railway at Otley, West Yorkshire	A660 bypass of Otley town (1984)
East Didsbury-Trafford Railway, Greater Manchester (closed 1967)	Opened as Metrolink light rail (2013)
Cambridge-St Ives Railway	Cambridge-St Ives Guided Busway (opened 2011)
Canal Towpaths in West London + Grand Union Canal	TfL 'Cycleways' (formerly 'Quietways') (2013 to date)
Parts of London road network	London on-street Cycle Superhighway Network – re-purposed road space (2008 to date)
A3 Hindhead single carriageway road	Road decommissioned, returned to nature & sandstone footpath in Hindhead Commons AONB (2011)

It is worth considering why these examples of re-use of infrastructure have occurred:

- a new form of demand has arisen or been identified, to use (some of) the assets – particularly the land, the graded/aligned right of way and some of the structures;
- the demand for the original use was declining in many cases (though not all);
- in each case, the opportunity to re-use the assets has been identified and taken – in some cases this has involved some far-sighted investment and re-planning of the network (e.g. shifting the East Coast Main Line; the Hindhead tunnel; recognising the value of recreational walk / cycle trails; providing healthy commuting routes / mode

options; switching redundant heavy rail assets to road / light rail / recreational trails; bypassing communities; etc.).

Most, though not all, of the assets in the list were built as railways – these are attractive for re-use because:

- they are suitably graded and aligned – relatively flat and gently curving, allowing for ease of access by other modes: cycle / walk / bus / light rail / mixed motorised traffic / etc.;
- in many locations they offer a separate route, away from the safety risks, noise, and air pollution associated with the road network[55].

Re-use options within the rail mode may also be relevant – e.g. rail lines designed for passenger use could have option value for freight use. Not all disused railways and canal towpaths have been re-purposed as described above – in some locations there is no need (demand) for additional roads/trails because the network is already dense enough, and in other locations there have been barriers to re-use such as private ownership of the land.

In summary, there may be positive option value associated with new infrastructure in specific locations. Whether this could be foreseen and whether it is feasible to include this in appraisal would require further thought. DfT might want consider whether its existing Option and Non-Use Values guidance (and underpinning research) could be adapted to develop a practical approach. The goal could be something that is capable of capturing the re-use option value associated with expensive new infrastructure.

Options to decommission

On the other hand, the review identified that the decommissioning costs of flood defences and power stations are part of the RV (or NPV) calculations in those sectors[56]. It may be the case that a consistent approach in transport would be to include the decommissioning costs of transport infrastructure *where this can be foreseen*.

This may be rare – many examples of decommissioning, including railways & canals, and the former A3 route at Hindhead (2011) and the former A344 adjacent to Stonehenge (2013), would almost certainly not have been foreseen when the infrastructure was planned.

A counter-example is the Chelmsford Army & Navy Flyover – decommissioned and removed because renewing it would "encourage more car journeys, rather than supporting the Park and Ride and encouraging walking and cycling, which goes against the aims of the Chelmsford Future Transport Network Strategy" in 2019 (Essex County Council, 2021). The flyover was originally built as a temporary structure with a 25 year design life, and opened in 1978. That was in practice extended to 41 years, before decommissioning. If such a 'temporary structure' was planned today, it would be consistent with the approach in other sectors to include decommissioning costs.

Options to defer

There has been some discussion during the writing of this paper, around the option to defer investment in new infrastructure into the future, rather than investing now (or vice versa).

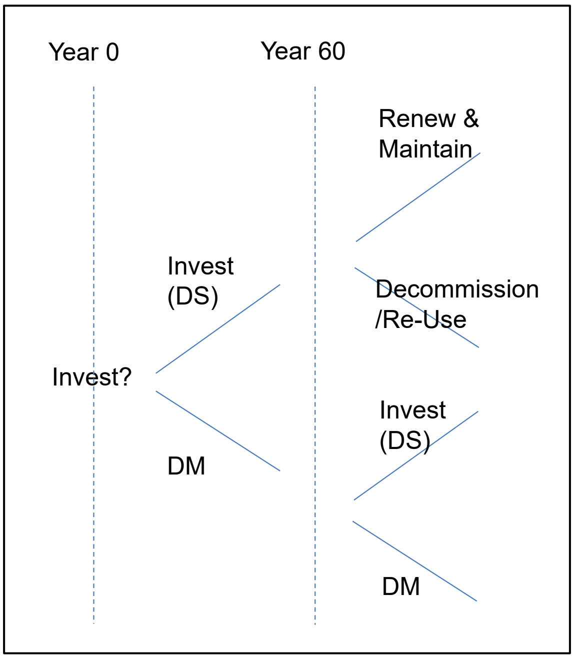
[55] canal towpaths have some of the same advantages as railways – predominantly flat and often environmentally favourable – but new investment in inland waterways is generally not a factor in the UK

[56] see section 2.4 re. flood defences

Investing now creates the option to keep the project open at the end of the appraisal period (60 years) if demand is sufficient, while instead opting for the Do-Minimum now creates the option of investing in future (say in 60 years' time) if demand has grown sufficiently.

These situations can be represented by a *decision tree*. Figure 4 shows an illustrative example in which the value of choosing to invest in Year 0 is affected by the value of both possible outcomes in Year 60 and their probabilities. I.e. the residual value is not certain, and depends on the strength of demand for the project after Year 60. Similarly, if the Do-Minimum is chosen in Year 0, the value of that decision is affected by the value of both possible outcomes in Year 60. Whether the outcomes should be combined using an expected value or a form of real options analysis (Myers, 1977; Amram & Kulatilaka, 1999) is beyond the scope of this paper. However it is worth noting that the value of the Do-Something versus Do-Minimum comparison at Year 0 is potentially affected (reduced) by the existence of the option to defer investment to Year 60.

Figure 4: Investment decision tree with long term choices



3.8 Application of RVs to Transport Appraisal: Worked Example

Having identified the *economic net benefits* method and the *straight line depreciation* method as the two most promising RV methods for transport appraisal – for differing reasons (Section 2.5) – it is potentially useful to apply these to a worked example and examine the results. The worked example we assembled for this purpose is as follows:

- a 100km fast inter-city rail line (new build, costed at £80/km[57]);
- capital costs are broken down into components, in order to be able to apply the 'components approach' (Section 2.1; Jones et al., 2013/14)[58];

[57] at 2010 general price level, with construction occurring 2022-2031, assuming lower maximum speeds than HS2 and reduced tunnelling requirements but still at the high end of estimates in PWC's (2016) international benchmarking study for High Speed Rail.
[58] composition of the costs is based on available data for HS2 including DfT (2020a), HS2 Ltd. (2017), DfT (2013) and HS2 Ltd. (2012)

- operating costs over a 100 year period, assuming a 100 year nominal asset life for major components of the infrastructure, with shorter-lived assets 'rolled over' in the PVC the RV;
- rolling stock (additional fleet) is part of the project;
- benefits quantified as usual;
- broadly based on HS2 business case documents and other relevant sources.

The costs of this example are as follows (Table 11).

Table 11: Rail example – costs (2010 prices and Present Values)

Capital Costs, £m, PV:				**Asset Life, years:**
Infrastructure	7992			
Land and rights of way		*1158*		Perpetual
Earthworks		*606*		100
Tunnels, bridges & other structures		*2726*		100
Permanent way (track)		*533*		30
Electrication, signalling, telecomms & other equipment		*569*		30
Stations, depots, buildings		*1839*		50
Other		*561*		50
Rolling stock	587			35
Renewals	923			15
Operating Costs, £m, PV	2879			

In order to apply RVs, the following are also needed:

- Growth rates of key variables – in order to extrapolate over the long term;
- Other assumptions – e.g. long term demand trends based on population growth.

The variables needed include GDP and population growth, carbon values, and real terms cost indices for future renewals and replacements. Much of this is available from the TAG Data Book already, although the time series there generally stop at 2100. Up to 2131 is needed for this worked example. At present only the carbon values and values of travel time savings have High/Low or sensitivity test values. The DfT uncertainty toolkit and scenario data will be key to address risk and uncertainty, in due course. For the time being we assumed:

- Risk adjusted scheme costs (approach set out in TAG Unit A1.2): +15% on costs. This is a placeholder figure only. It is not out of line with some of the magnitudes of risk adjustment seen in transport projects where QRA has been undertaken, or the example in TAG Unit A1.2[59] – but longer term cost risk needs to be investigated;

- Benefits risk is also part of industry practice in QRA[60] – we assume -15% risk adjusted benefits.

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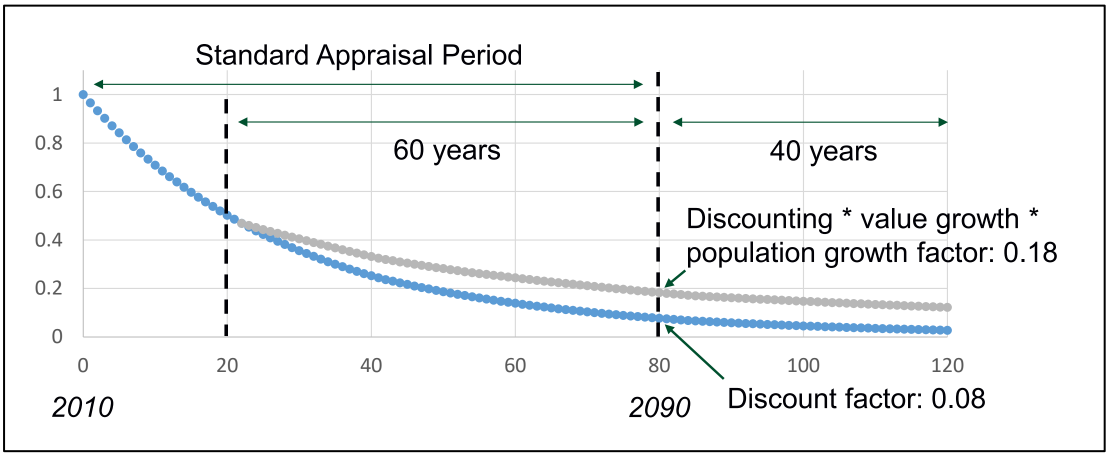
[59] the optimism bias adjustments at Stage 1 are larger than this, but are traded off against increasing risk adjustments as the business case is refined.
[60] e.g. Standard and Poors (2005), Flyvbjerg et al. (2006)

Of course, *discounting* is also needed. The positive social discount rates adopted in UK appraisal[61] and in comparator countries worldwide[62] imply that beyond some horizon, the contribution to NPV may become insignificant – but this depends crucially on the growth rate of benefits versus the discount rate, as shown in Figure 5, so it does not to lead to any unique recommendation for how long the RV period should be. The judgement used in New Zealand (Table 3) that 90% of the PVB should be captured by the NPV+RV could well be a pragmatic, useful target in setting the length of the RV period.

[61] HM Treasury (2020, Annex 6)

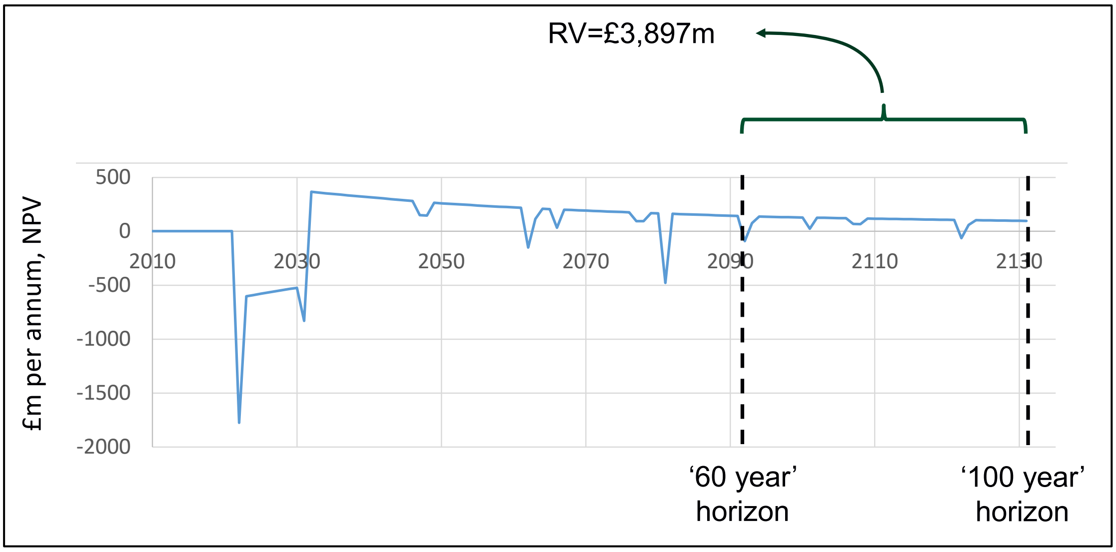
[62] see Table 3 above

Figure 5: Social discounting (at UK rates) and its effect on future net benefits in the worked example



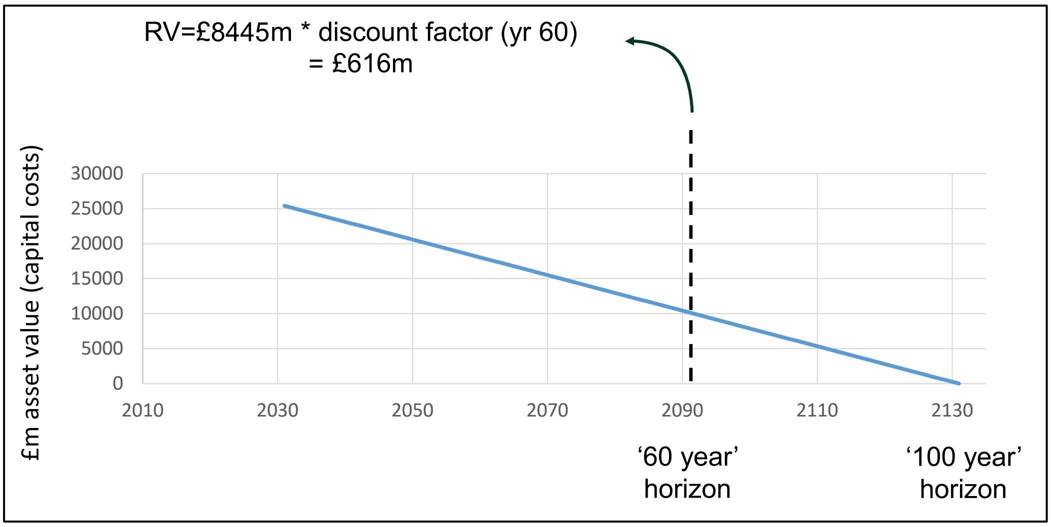
Using the *economic net benefits* approach (Figure 6) produces a residual value of £3,897million, on top of an NPV of £4,941million. The Figure shows the net benefit profile annually over time. The RV is large compared with the NPV because a large proportion of the costs fall in the standard appraisal period.

Figure 6: Net benefits, £ per annum (PV) 2010-2031, and Residual Value (economic method)



Using *straight line depreciation* instead of the economic net benefits approach, produces an RV estimate of £616m – this is the remaining asset value at end of the standard appraisal period (Figure 7).

Figure 7: Residual Value (straight line depreciation method)



Finally, Table 12 compares the results of the economic and straight line depreciation methods for the BCR, and includes the comparison with the standard appraisal period (60 years of operation) in the first column.

Table 12: Worked example - results

Appraisal Period	**60 Yrs**	**60 Yrs + RV (Econ)**	*RV Risk Adjustment*	**60 Yrs + RV (Econ) with Risk Adjustment**	**60 Yrs + RV (Depreciation in PVC)**	**60 Yrs + RV (Depreciation in PVB)**	**100 Yrs**
PVC (BTB), £m, PV	7091	7091		7091	7091	7091	7212
PVB, £m, PV	12033	12033		12033	12033	12033	16051
RVC (61-100), £m, PV		121	*15%*	139	-616		
RVB (61-100), £m, PV		4018	*-15%*	3416		616	
BCR	**1.70**	**2.23**		**2.14**	**1.86**	**1.78**	**2.23**
ΔBCR, %		31%		26%	10%	5%	31%

Note: RVC is the present value of costs during the residual value period; and RVB is the present value of benefits during the residual value period.

Including the economic RV raises the BCR from 1.70 to 2.23 in this worked example. The effect of the risk adjustments (to demand and costs) is to reduce this back to 2.14. The BCR using the straight line depreciation method depends on whether the RV is added to the PVB or deducted from the PVC, but in both cases is substantially lower than the economic method: either 1.86 or 1.78. Of course if the risk and uncertainty analysis found that the economic RV outcome in a particular scenario should have higher costs or lower benefits, this would narrow the gap. However BCR is relatively insensitive to % changes in RVC (because RVC is relatively small); and it would require a 64% reduction in RVB in this example to equalise the BCR with the depreciation method at 1.86.

To summarise some of the implications of this;

i) in the UK framework (TAG) a separate RVB and RVC are needed, because the RV contains both benefit and cost elements;

ii) that resolves the issue of whether RV should be added to the PVB or deducted from the PVC (see international practice above), when the *economic method* is being used;

iii) risk adjustment matters – but if it can be quantified, the economic net benefits approach may produce substantially larger benefits than straight line depreciation (as well as being theoretically more consistent);

iv) various detail issues were resolved during the working – e.g.:

- in the depreciation method, the example includes RVs for shorter-lived cost items that renew before the 60 year horizon, not only the 100 year or perpetual items;
- how to treat land costs and other 'perpetual' costs in straight line depreciation;

v) the 'component approach' is feasible (and preferred) when using a depreciation method; and

vi) both road and rail projects have a large % of costs that are 'perpetual' or have a 100 year asset life (based on HE/NR data), e.g. 82.5% of roads (excluding structures). This has comparability implications.

3.9 RVs in the Financial Case

As was noted in Section 2, residual value also has a role in the Financial Case, to determine the value of the asset(s) at the end of the appraisal period. This may be relevant if assets can then be sold or transferred (or leased), e.g. sale of rolling stock or infrastructure assets (such as HS1), *and if* that is foreseen at the time of appraisal – in one of the scenarios that form part of the future outlook for this project.

An interesting application is the Residual Value Mechanism (RVM) introduced by DfT in 2015, to incentivise passenger rail franchisees to invest in franchise assets where the asset does not have a commercial return within the life of the franchise – but does if the subsequent franchise period is included. The transfer value of the asset or scheme, from one franchisee to the next, is based on an assumption that the asset will be fully depreciated over a defined period (asset life), and straight line depreciation is applied from purchase through transfer to the end of the asset life (DfT, 2017e; DfT, 2019b). This is good example of an intervention which uses RV to correct a market failure, providing efficient incentives where before they were lacking due to the (quasi-) market structure.

3.10 Criteria for the Use of RVs

Finally, we have given some thought to what the criteria are for the use of RVs. DfT's questions ask what is appropriate – this is an attempt to provide a checklist against which the emerging methods/future appraisal guidance could be checked:

- Is it theoretically justified, in other words in the theoretical framework is there a case for it?
- Is it practically feasible? E.g. do the evidence and tools exist to implement it?
- Is it proportionate? I.e. does the benefit in improved decision making outweigh the costs of implementation?
- Does the implementation of it create any perverse incentives? How does it fit with the overall incentive properties of appraisal and evaluation?
- Is this the best of the methods suggested / available?

The third criterion relates to the New Zealand-based target of capturing 90%[63] of the PVB. If methods do not contribute to a significant change in PVB, so that for example the PVB without RVB is >=90% of the PVB including RVB, then there is no need to carry out detailed calculations of the RV.

[63] or another % of the total

4. Answers to Key Questions

In this section we attempt to provide answers to the main questions specified by DfT at the start, using the findings from the previous sections of the paper.

1. Whether and when it is appropriate to consider the residual value at the end of any given appraisal, whether that is the current maximum of 60 years, or a potentially longer period.

There is a principles-based answer to this question, and then an answer taking into account wider criteria set out at the end of the last section.

The principles-based answer is 'yes', it is appropriate to consider any residual value at the end of the appraisal period, in line with the economic principles of cost-benefit analysis (e.g. Boardman et al., 2018; De Rus, 2010). More broadly, it is appropriate to consider any future costs and benefits of an investment over the life of the assets involved (typically, in line with the life of the longest lived asset). Noting that the appraisal period may differ from the longest lived asset, the following scenarios may arise:

a. Appraisal period = (longest) asset life. In this case, the appraisal would naturally cover all expected costs and benefits over the useful asset life, and any RV would likely be very modest, only including any scrap value and/or remediation/decommissioning costs, and possibly some option value. In this scenario, an RV method is not likely to change the VfM category of the project. This is the approach taken in transport appraisal in the Netherlands.

b. Appraisal period < (longest) asset life. The appraisal period would omit part of the future costs and benefits over the useful asset life. Inclusion of RV is necessary and may be large enough to influence the VfM of the project. The RV approach should aim to capture all net benefits beyond the appraisal period for the remainder of the asset life. In principle, this should be equivalent to increasing the appraisal period to align with the asset life.

In the presence of uncertainty, it is important that all the benefits, especially those further into the future, are assessed using methods which address risk and uncertainty (e.g. the forthcoming DfT uncertainty toolkit). The benefits included in the appraisal should be risk-adjusted where significant risk is identified, and should be sensitivity-tested against scenarios (e.g. the Common Analytical Scenarios).

Considering the wider set of criteria at the end of Section 3:

- How practically-feasible is the adoption of RVs or a longer appraisal period? As shown in this paper, the steps involved are all feasible – whether a net benefit based or an accounting (depreciation) approach are adopted – and a similar approach is used in the Netherlands. The evidence base would ideally be reviewed on growth rates of key variables in the long term, and the approaches to uncertainty and the longer appraisal period would be aligned.
- Is the suggested approach proportionate? The approach largely relies on pre-existing data and extrapolation of growth trend, under different scenarios. Analytically this is not demanding. Any organisation preparing a multi-million or multi-billion pound infrastructure project should be able to undertake the analysis. Straightforward

guidance including default assumptions (and spreadsheet tools) could be provided to ensure that projects at the lower end of the cost range are not over-burdened.

- What about incentives? Including the longer term (beyond 60 years) in appraisal fits well with an agenda to reduce perverse incentives. Curtailing the appraisal period at 60 years for projects which have very long term implications, risks biasing investment decisions. This is more true in an environment of low social discount rates. There is no guarantee that comparing projects using only the first 60 years of operation will give an equivalent ranking of projects – indeed it would be expected to bias investment decisions away from projects with long term (or perpetual) impacts. (Sections 3.4-3.6 suggested that a fairly wide range of transport projects may fall into that category).

2. How should residual values be best calculated within transport appraisal? In particular:

This note suggests that the best method to calculate RVs is a net benefits-based method, wherever the appraisal period is shorter than the asset life (extrapolating all net benefits until the end of the asset life). In practice, it may useful to define a default horizon for the RV (such as 100 years from the opening year), in order to avoid wasted effort in relation to very small future benefits (after discounting).

As part of this, strengthening the approach to uncertainty in appraisal (which DfT is already undertaking) is key.

2a. Under what conditions might residual values reflect the wider social and economic benefits of assets?

Under a benefit-based method (i.e. a method where RV is calculated based on the benefits of the project and not only on the costs). On the other hand, under accounting methods (e.g. depreciation approach), RV would not reflect any wider benefits. The challenge with benefit-based methods is the extrapolation of benefits beyond the end of the current appraisal period.. This could be enabled by clear, proportionate guidance on the growth rates to be assumed for the key variables over the long term, including growth rates for the values of time, safety and environment, modal demand, cost rates, and trends in the main external effects (e.g. carbon emissions, accident rates, & growth assumptions for WEIs) – some of this is already present in the TAG Data Book, and would those series would require extension to the 2130s (to give 100 years from around 2030).

2b. Are there any methods or approaches which would allow us to reflect the wider social and economic benefits of an asset when calculating residual values?

Yes, benefit-based methods. These are recommended in the CBA literature, and are used in the Netherlands. This note has considered their application in the UK. DfT has previously explored this as part of the Appraisal Periods Consultation. In this note, we have suggested that a Residual Value beyond 60 years, and capping the RV period at 100 years, would be pragmatic steps.

3. Related to (2), what are relative merits, or otherwise, of ‘market based’ valuation approaches which seek to value the right to run a transport service as a concession, or the value of the infrastructure manager.

A market does exist for current transport infrastructure – the note identified a number of examples of DfT selling transport infrastructure (e.g. HS1) or letting concessions or franchises. In cases where DfT is considering a relatively short-term decisions such as franchising a service for 15 years, there might be some advantage in looking at market-based values for the re-allocation of any assets at the end of such a short franchise period. Even in this case, judgment would be required, to forecast asset values 15 years into the future.

However, a market-based approach to RV in appraisal would suffer some key limitations:

- Estimation for an ex-ante appraisal would be challenging, since the prospective sale or lease would occur decades into the future. The relevance of a 'market based valuation' when markets for future infrastructure do not exist, is questionable.
- Market values tend to be driven by financial prospects – hence depend on revenues and costs. This is inconsistent with the goal here, which is to estimate the future benefits and costs, including multiple social and environmental impacts.

4. Alternative potential approaches for calculating residual values in appraisal and their strengths and weaknesses, both in theory and with regards to practicality of implementation.

The report considered residual value approaches based on:

- economic net benefits;
- straight line depreciation;
- other depreciation approaches.

Implementation of the first two of these was scoped and tested using a UK example.

The economic net benefits approach is more consistent with theory and principles. If is it implemented alongside practical guidance on long term growth rates and treatment of uncertainty, then it is both practical and more consistent with principles.

Using straight line depreciation instead, is a somewhat simplified approach resting on the costs rather than the benefits. As such it leaves evidence about benefits on the table, yet it still requires assumptions (about asset life and – implicitly – the period over which the benefits should be counted).

Practice around the world includes both jurisdictions where straight line depreciation is used, and also jurisdictions where the net benefits-based approach is used, for transport infrastructure appraisal. Given this, it may be preferable to choose the approach that is more complete theoretically and empirically.

Note that to apply either approach in the UK requires some adaptation, to fit with our BCR methodology. (Longer term PVB and PVC components feed into different parts of the BCR, so a single residual value does not work. An RVB and an RVC are proposed, to address this).

5. The implications of different approaches to appraising residual value for the comparability of appraisal results across different modes and schemes.

Comparability across modes and schemes requires:

- an understanding of the period over which benefits will be generated;

- a method for comparing like with like across interventions where the time period differs.

Our research has updated previous findings on asset lives across modes and asset components (see Sections 3.4-3.6).

The theoretical literature is clear that projects cannot be compared using the NPV when they have different appraisal periods. However methods such as the 'roll-over method' and Equivalent Annual Net Benefit (EANB) method are recommended (Boardman et al., 2018). It is suggested elsewhere in the literature that using BCR overcomes the issue with NPV. Our conclusion is that this is not strictly correct, as there is scope for differing growth rates of benefits and costs, and different discounting profiles, to vary the BCR for each renewal of the 'rolled-over' project.

EANB is not suitable as the main metric in a DfT context because it is not a value for money metric, only a value per unit of time metric. Therefore the roll-over method, leading to a comparison of BCRs, is perhaps the best solution, and a standard appraisal period of 60 years (for infrastructure) and a typical RV period of 40 years (for infrastructure) would provide a common basis.

6. The extent to which different approaches to residual valuation can accommodate the full range of expected welfare effects, including social, environmental and wider economic benefits.

Only a benefit-based method to calculate RV has the potential to accommodate the full range of welfare impacts.

7. What approaches are taken in other countries and industries for reflecting residual values in appraisal/investment decision making?

A review of approaches in other countries and industries is provided in Sections 2.2 and 2.3.

Both the economic net benefits approach and the straight line depreciation approach see some use. For the reasons discussed in this note, and summarised in answer 4. above, the economic net benefits approach has advantages, as an evidence-based, theoretically consistent method.

5. Conclusions

In conclusion:

- for appraisal guidance to be useful, it needs to be practical, implementable – and in UK terminology methods need to be 'proportionate';
- that means effort should be channelled into aspects of the appraisal which could make the most difference to value for money and overall public value (BCR, NPV), rather than that focusing excessive effort on details;
- inclusion of long term benefits is not a detail – the potential impact on value is large, as the HS2 case and the rail worked example in this paper show;

- the New Zealand method has an attractive criterion: that the RV should be calculated if necessary to ensure that more than 90% of the PVB is measured;
- there are two feasibility issues though – for the economic net benefits method: uncertainty, and the need for new (and longer) series of key variables in order to extrapolate costs and benefits to the end of the RV period;
- uncertainty plays in at least three different ways – (i) it undermines the value of long term investments since the prospects of the infrastructure fulfilling the exact same role for 100s of years are affected by technological, social, economic and environmental change; (ii) well chosen long term investments may be well positioned for the *upside* risks associated with rising demand for cleaner, net zero transport (for example); and (iii) because some forms of investment create options for future use (e.g. railway re-used as a trail/bridleway, or as a road) which then becomes an additional positive source of value from the initial investment. This is undeniably complex, but a significant part of it falls within the scope of the forthcoming uncertainty toolkit;
- the need for new (and longer) series of key variables is perhaps more easily solved: the worked example in this paper was able to fill in the gaps using a combination of available data and reasonable economic assumptions;
- the consistent and comparable treatment of modes is also a key issue. The paper has shown that creation and allocation of rights of way have long term consequences. If the right of way is kept in its existing use for 100 years or more then we need to deal with that very long term horizon. We have suggested that RVs may be a useful tool for dealing with this, and have set out how DfT could move towards using them. This would be consistent with the Green Book principles and go beyond the (rather general) Green Book guidance, and it is worth noting that RVs are a concept with a solid grounding in economics and in use internationally in finance and economic appraisal – many practitioners will be familiar with the concept from their studies and application will be eased by that.

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Appendix A: RAILPAG Useful lives of railway asset components

Infrastructure components

Type of infrastructure	Element of infrastructure	Years
Earth works	Small embankments in soft grounds	50
	Large embankments in stable grounds	100
Tunnels, bridges and other works	Drainage works	80-100
	Very large works (tunnels, viaducts)	80-100
Access facilities and stations	Structural elements (façade renovation, drainage structures)	10-50
	Elements of habitability	2-10
	Aesthetic elements	1-5

With regard to track superstructure equipment, its lifespan depends largely on the volume of traffic sustained and speed. Representative values are shown in the next table; the component having the shortest life is the ballast, which requires partial renovation without changing rails or sleepers.

Track superstructure components

Component	Expected life Million gross tons	Life in years for an average traffic of 35,000 t/day
Rail UIC-60 in ballasted track	500	40
Concrete sleepers	500	40
Ballast	250	20
Safety facilities		10-50
Electrification facilities (distribution and sub-stations)		10-50

Regarding rolling stock, the expected life depends on the speed characteristics of the material and the type of service it is assigned to.

Rolling stock

Type of vehicle	Top speed	Years*
Freight wagons for conventional lines	Speed under 100 km/h	40
Freight wagons for both conventional & high-speed lines	Speed over 100 km/h	30
Passenger cars for long distance and regional services	Speed over 120 km/h	25
Passenger cars for suburban and metropolitan services	Speed under 120 km/h	15
Motor train unit	Speed under 120 km/h	15-25
Locomotives for services in conventional lines	Speed under 200 km/h	25
Locomotives for services in high-speed lines	Speed over 200 km/h	20
Cars for high-speed lines	Speed over 250 km/h	15

*Some internal elements, such as the interior of passenger cars, may have a shorter service life. This may mean refurbishing a vehicle before the end of its service life.

Source: EIB & EC (2005)