NetworkRail

Life Cycle Cost Manual:

Guidance to support option selection for investment projects

February 2017

FOREWORD

Investment decisions taken now on sustaining or enhancing the railway infrastructure have implications for customers and taxpayers for decades to come. There are countless examples in rail and other sectors where the longer-term implications of investment decisions have been neglected, with the consequence that the benefits do not materialise as anticipated or excessive maintenance costs are incurred. The risk of this happening in railway projects is higher because the in-service ownership costs for long-lived infrastructure assets can be much higher than the acquisition costs.

Life Cycle Costing (LCC) is a proven methodology for balancing the cost of acquisition with the long-term costs of maintenance, operation and disposal. The scale of investment in the railway and the importance of its performance to the GB economy means that Network Rail should have a capability in LCC that is demonstrably on a par with best practices in aerospace, defence and the off-shore oil and gas sector.

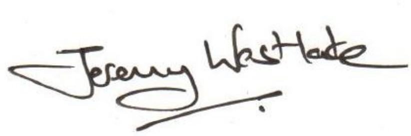
Two years ago we mandated LCC on all Network Rail renewal and enhancement capital works projects and programmes. We recognised that the journey to fully embedding LCC as a core business process is a long one. The next stage is focussed on supporting the business in adopting LCC on all projects which will be achieved by:

- Ensuring that there are sufficient competent resources with specific accountability for implementing LCC in investment projects;
- Aligning LCC processes with other investment planning processes, such as business planning and risk and value management;
- Developing and applying methods and models selected from the most advanced proven techniques;
- Providing training for our investment teams in the essentials of LCC and building a core of LCC practitioners for undertaking specialist assessments.

This manual has been developed to support the implementation of these initiatives, providing specific guidance about what needs to be done, when it needs to be done, who needs to do it and where to go to for help. Guidance is also provided on the templates, models and case studies that have been developed to make assessments as easy to implement as possible, to improve their reliability and to produce consistent outputs that interface with other dependent processes.

More information is available via the Connect webpage which includes case study examples, access to training programmes, and previously analysed asset life cycles that can be applied in multiple projects.

http://connect/communities/LifeCycleCosting/default.aspx



Jeremy Westlake
Chief Financial Officer

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GLOSSARY

AFC	Anticipated Final Cost
ALP	Asset Lifecycle Profile
CoBALT	Cost Benefit Asset Lifecycle Tool
CSM	Common Safety Method
DPE	Designated Project Engineer
GRIP	Governance for Railway Investment Projects
LCC	Life Cycle Cost(ing)
NPV	Net Present Value
NR	Network Rail
RAM	Route Asset Manager
STE	Safety, Technical and Engineering directorate
VM2	Second Value Management workshop
WLC	Whole Life Cost

1 OBJECTIVES AND SCOPE OF LIFE CYCLE COSTING

1.1 Introduction

Life cycle costing (LCC) has grown in popularity because it has proven to be the most intuitive and accepted means of ensuring that decisions taken during the procurement stage of major capital projects balance the cost of acquisition with the long-term costs of maintenance, operation and disposal.

LCC was first introduced by NASA and the US Department of Defense in the 1960s following a number of high profile projects in which the running costs and level of equipment failures turned out to be much higher than anticipated, often dwarfing the initial capital outlay. The systematic adoption of LCC had a transformative effect on the procurement of complex capital equipment which led to the approach being widely adopted across many industrial sectors.

The rail sector in the UK has a long history of participation in cross-sector developments of LCC methods and standards but there has been limited application on real projects. This has started to change following the mandating of LCC in 2014 on all Network Rail renewal and enhancement capital works projects and programmes, including those which are third-party funded.

The purpose of this document is to support the embedding of LCC in the business by providing practical guidance to the people responsible for implementing this requirement, including Sponsors, Project Managers, Cost Planning Managers, Route Asset Managers and Project Engineers. The document is structured to provide guidance on the:

- Concepts of life cycle costing, its scope and when it should be applied
- LCC process, including the definition of responsibilities and accountabilities for key roles
- Recommended methodology at each stage of the GRIP process
- Analysis tools, data and other information available to support a LCC assessment
- Required outputs and deliverables from a LCC assessment
- Training and analytical support available to project teams

1.2 Concepts of life cycle costing

1.2.1 Definitions of key terms

There are numerous LCC related standards in the public domain, the majority associated with specific sectors e.g. defence, or asset types e.g. buildings. The most widely referenced generic standard which is particularly suited to engineering assets is EN 60300-3-3 (Ref. [1]). The application guide and its revision (Ref. [2]) underpins the LCC process described in this document and is a key reference in the development of the methodology, models and supporting information. The RICS guidance (Ref [3]) provides a broader explanation of some key terms and has also been used. Definitions for key LCC terms are provided at relevant stages throughout the document, starting with three basic terms:

Life cycle costing: The process of economic analysis to assess the cost of an item over its life cycle or portion thereof (Ref. [2])

Life cycle cost / Whole life cost: The total cost incurred during the life cycle[1]. (Ref. [2])

Life cycle: Series of identifiable stages through which an item goes from its concept to disposal. (Ref. [2])

[1] Ref. [2] uses the same definition for LCC and WLC which is consistent with its interpretation in Network Rail, where the terms are used interchangeably.

Ref. [2] recommends that each organisation specifies the stages in the asset life cycle that best reflect its business needs. The following have been adopted by Network Rail and are commonly used by other railways and other asset intensive companies.

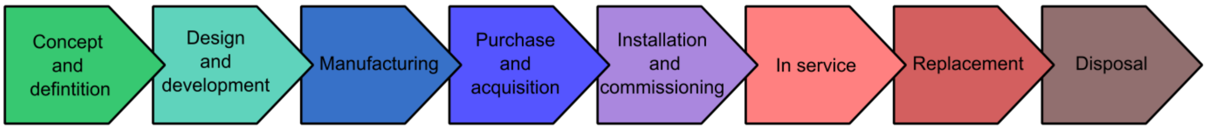

Figure 1 – Key stages in the life cycle

1.2.2 The basic LCC methodology

The determination of the life cycle cost involves the quantification and aggregation of the costs incurred at each stage of the life cycle associated with an asset or component of an asset. As illustrated in Figure 2, the analysis involves three major dimensions:

1. The stages of the life cycle
2. The asset or asset component
3. The cost incurred due to:
    a. An intervention undertaken on the asset or asset component e.g. preventive maintenance and the breakdown of that cost e.g. plant, labour, materials etc.
    b. The operation of the asset or asset component e.g. energy consumption
    c. The financial value of consequential costs when an asset or asset component fails or is unable to deliver its intended purpose. These are sometimes referred to as intangible or risk costs and include factors such as safety exposure, service failures and reputational damage.

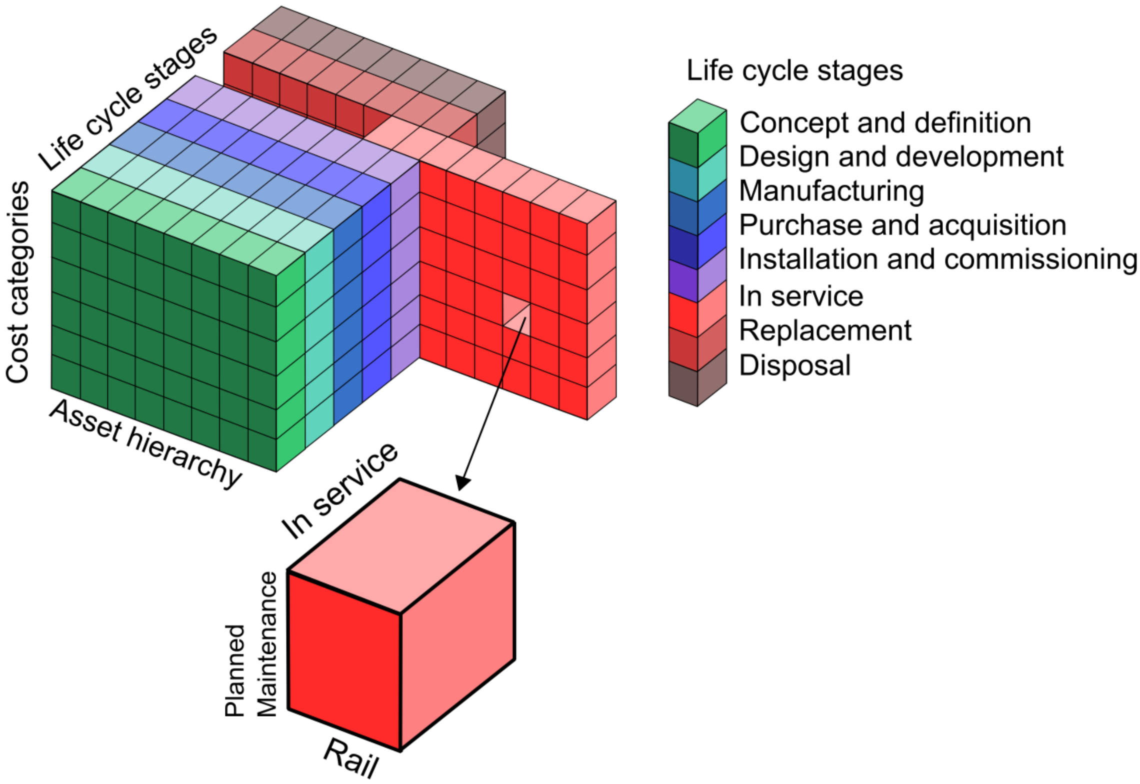

Figure 2 – Illustration of how the cost profile is constructed in a LCC framework. Derived from Ref. [2].

It is important to note that the LCC is inclusive of all tangible and intangible costs incurred over the life cycle. LCC does not however include value outcomes, such as revenue or journey time savings. This is discussed further in Section 1.3.2.

The benefits of LCC are greatest when it is applied in the early stage of the life cycle, particularly during concept and design. This is illustrated in Figure 3 which compares the committed cost of a typical project with the actual cost at each stage of the life cycle. After the item enters service the ability to influence costs is significantly reduced, although Figure 3 also acknowledges that the uncertainties are greatest during the early stages.

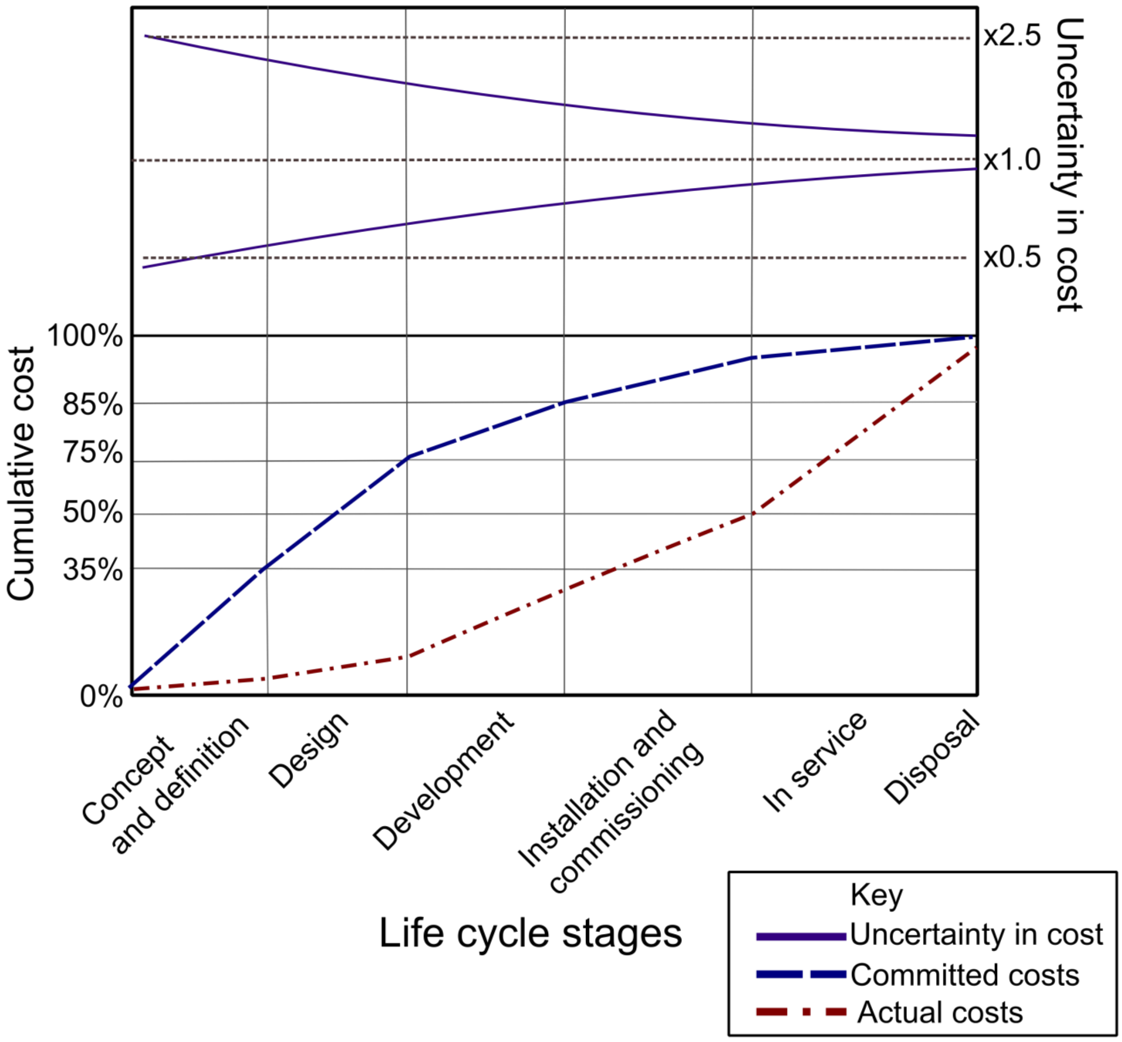

Figure 3 – Illustration of committed and actual costs at each life cycle stage. Extracted from Ref. [2].

1.3 LCC interfaces

1.3.1 Interface between LCC and safety requirements

The guidance provided in this document is focussed on supporting the selection of options associated with infrastructure changes in the early GRIP stages (GRIP 2 and GRIP 3) based on a comparative economic assessment of the life cycle costs and cost savings of each option. The cost of safety improvements and the monetised cost of safety risk associated with the implementation of each option are considered insofar as they have a significant impact on the economic comparison.

It must be emphasised that LCC assessment as proposed in this document is not intended to meet, in part or in full, the requirements of the Common Safety Method (CSM). The CSM is mandated on all projects that introduce a significant technological, operational or organisational change to the railway system in order to demonstrate that the risks resulting from the change are as low as reasonably practicable. It is important for projects to ensure that the economic and safety processes are joined up. The LCC assessment may be used in support of, but is not a substitute for, the suitable and sufficient risk assessment necessary to meet the requirements of safety legislation.

1.3.2 Interface between LCC and the socio-economic business case

As stated in Section 1.2.2, LCC does not include value outcomes such as revenues from or socio-economic benefits of an investment scheme. The LCC and value outcomes are brought together in the socio-economic business case evaluation. LCC provides therefore the cost input to the business case. The socio-economic benefits in the business case include, but are not restricted to, the following:

- Benefits to rail users e.g. journey time savings
- Benefits to non-rail users e.g. road decongestion benefits due to modal shift

1.4 Scope of LCC assessment for an investment project

The scope for LCC specifies when the process should be applied e.g. the relevant GRIP stages and stages in the asset life cycle. It also identifies which cost categories need to be considered in a LCC assessment.

1.4.1 Applicability of LCC at each GRIP stage

LCC is a methodology that is widely used across Network Rail, supporting, for example, the development of Asset Policies, the planning of and the allocation of budgets to renewals and maintenance, and the appraisal of tenders for new products.

For projects, the maximum benefit from adopting a LCC approach is during the feasibility and option selection phases - GRIP stages 2 and 3 respectively. The guidance provided in this manual will therefore apply to these two stages.

As a consequence of limiting the scope of this guidance to that required for decisions at GRIP stages 2 and 3, a comparative rather than an absolute assessment is required. This means that it is necessary to analyse only the factors that cause a difference in LCC between options; it is not necessary to analyse factors that are identical for all options.

Although the current priority is to improve decision making at GRIP stages 2 and 3, the mandating of LCC applies to all subsequent stages. The benefits from continuing to analyse and monitor the LCC are most evident during project design, tender development and appraisal, and post installation to validate the assumptions made about aspects such as reliability, performance and component selection in the analysis. The methodology and tools described in Sections 3 and 4 are equally applicable to such assessments and more detailed guidance in these areas will be considered in future releases of this document.

The cost of performing a LCC assessment has also been considered in defining the scope of projects that should be assessed. As a result, the threshold for undertaking a formal LCC assessment has been set at £3m (estimated acquisition and installation cost). Above this value, the guidance provided in this document should be followed. Below the threshold, it is sufficient to show qualitatively that LCC principles have been adopted in determining option selection, in particular adherence to Asset Policy.

For the majority of projects, the same benefit will apply to each option, so the life cycle costs can be compared on a like-for-like basis. In some cases, lower LCC options may be identified that may not deliver the whole benefit of the scheme. These should not be automatically discounted but resolved in consultation with the team developing the business case (see Section 2 below).

In summary, the guidance relating to the decisions within the scope of a life cycle cost analysis is as follows:

- A formal LCC analysis, following the guidance in this document, should be undertaken for all capital projects over £3m.
- Where this threshold is exceeded, a comparative LCC analysis is required at GRIP stages 2 and 3.
- Below the threshold, it is sufficient to show qualitatively that LCC principles have been adopted in determining option selection.

1.4.2 Cost components

The most common cost categories featuring in railway LCC assessments are the costs associated with interventions, the costs of asset failure, or other costs not directly related to the assets. These are summarised below:

Intervention and operational costs:

- Design
- Installation (new asset)
- Inspection
- Operations
- Planned maintenance
- Reactive maintenance
- Refurbishment (replacement of a component of an asset)
- Renewal (replacement of a complete asset)
- Disposal

Intangible costs:

- Safety risk (quantified as Fatalities and Weighted Injuries)
- Environmental impact
- Service risk due to train delays
- Reputational impact e.g. from possession overruns, accidents etc.

As discussed in section 1.2.2, the cost categories listed above are within the scope of the LCC and are brought together with the socio-economic benefits in the business case. The LCC process assumes that there are a number of infrastructure options that can deliver the required business outcome and seeks to evaluate which one has the minimum cost over the project life cycle. In some cases, this is an over simplification as different infrastructure options may give rise to different outcomes and hence different benefits. This requires effective management across the interfaces between the teams working on the business case, Cost Planning, LCC, risk and value etc. which is a key part of the Sponsor's and Project Manager's roles.

2 LCC PROCESS, ROLES AND RESPONSIBILITIES

2.1 Overview of the LCC process

The recommended LCC process applicable to GRIP stages 2 and 3 is shown in conventional swim-lane form in Appendix A. The purpose of the LCC process at each GRIP stage is summarised below and the key roles and responsibilities are described in Section 2.2.

2.1.1 GRIP stage 2

At GRIP stage 2, the objective is to consider a broad range of potential infrastructure options that may be capable of delivering the outputs assumed in the business case. In some cases the solution may be obvious e.g. to comply with asset policy or to use a precedent from a similar project. In such cases the LCC assessment can be completed at GRIP stage 2 with no further analysis required.

In other cases, where there is a range of credible options, a qualitative LCC analysis is recommended, which may be sufficient to identify the optimum solution or, more likely, be used to reduce the number of options to a shortlist for further consideration in GRIP stage 3.

2.1.2 GRIP stage 3

At GRIP stage 3, the objective is to identify the optimum LCC solution from a shortlist of options generated during GRIP stage 2. The steps in the LCC process focus on the quantitative analysis that is usually required to differentiate between the options. The methodology underpinning these process steps is described in Section 3.

During this GRIP stage, the acquisition and installation costs should assume the GRIP stage 2 Cost Plan Anticipated Final Cost (AFC) because the GRIP stage 3 Cost Plan AFC tends only to be progressed for the preferred option. For the majority of infrastructure options under consideration, the through-life costs e.g. maintenance, service impact etc. will be available in a templated format (Section 4) from the Safety, Technical and Engineering (STE) directorate's WLC team. In some cases, these will need adjusting to reflect local conditions e.g. traffic density. In rare situations where new asset types are being considered e.g. platform surfaces, it may be necessary to estimate the through-life costs from first principles.

The output from the process at GRIP stage 3 is a quantified comparison of the LCC for each option considered. LCC is one of several factors considered in the ultimate option selection process which is managed by the Value Management workstream – the LCC outputs at GRIP stage 3 are input to the second Value Management workshop (VM2).

2.2 Roles and responsibilities

The process diagram provided in Appendix A identifies seven key roles in the LCC assessment at GRIP stages 2 and 3. There are a further three roles which do not have responsibilities or accountabilities in the LCC process but provide interfaces with other interdependent processes. Both types of role are described below. Although responsibilities and accountabilities have been assigned to individual roles the LCC process is iterative and collaborative.

2.2.1 Roles with LCC responsibilities

Sponsor

The Sponsor is ultimately accountable for the LCC assessment being carried out, setting the objectives and terms of reference, remitting the Project Manager, managing the interfaces with other projects, allocating funds and approving the preferred option. The Sponsor should be proactive in ensuring that the LCC assessment is properly represented when the option selection decision is made e.g. during VM2.

The Sponsor may be a dedicated role or could be fulfilled by a number of different roles that have sponsorship accountability e.g. the Route Asset Manager (RAM).

Project Manager

While the Sponsor sets the terms of reference for the LCC assessment, the Project Manager is responsible for overseeing its delivery. The Project Manager receives a remit from the Sponsor and identifies or refines the options to be considered, specifies the methodology to be adopted (consistent with the guidance in this document), sets the timescales for completion of the assessment and remits the Programme Cost Planning Manager to undertake the work. The Project Manager monitors the delivery of the work, provides support for the safety and sustainability sections (as per the process map in Figure 10), approves the LCC report and submits the conclusions to the Sponsor.

Programme Cost Planning Manager[2]

The Programme Cost Planning Manager reviews the LCC requirements of the Sponsor with the Project Manager and then agrees the inputs, outputs and duration necessary to deliver those requirements and allocates a competent person or persons (usually a Cost Planning Manager) to carry out the LCC assessment. The Programme Cost Planning Manager is the main point of contact for the Project Manager during the assessment and is responsible for the handover of the LCC output on its completion.

Cost Planning Manager[3]

The Cost Planning Manager is responsible for undertaking the LCC assessment and requires competency in the application of the methodology and tools used to support the analysis at GRIP stages 2 and 3 (Sections 3 and 4). The Cost Planning Manager is responsible for producing all the documentation associated with the delivery of the LCC assessment including reports and records of calculations.

Route Asset Manager (RAM) – when not the Sponsor

The RAM is required to provide confirmation that the through-life costs assumed in the LCC assessment have been appropriately sourced and are fit for purpose.

Designated Project Engineer (DPE)

The DPE is responsible for interpreting and applying Asset Policies to the options under consideration, advising the Sponsor and Project Manager on whether the Asset Policies contain sufficient direction to identify the option with the lowest compliant LCC or whether additional analysis is required at either GRIP stage 2 or 3.

[2] Known as Estimating Managers at time of publication; however there is an expected change of job title to Programme Cost Planning Manager and this term will be used throughout this document.
[3] Known as Estimators at time of publication; however there is an expected change of job title to Cost Planning Manager and this term will be used throughout this document.

Safety, Technical and Engineering - WLC team

The STE WLC team is responsible for defining the generic methodology for undertaking a LCC analysis at GRIP stages 2 and 3 and for developing, maintaining and providing access to central models and life cycle information. Where requested, the WLC team will review and comment on LCC assessments undertaken by the Cost Planning team, although approval of the LCC deliverables is the responsibility of the project team.

2.2.2 Roles with LCC interfaces

Economic Analysis team

The Economic Analysis team is responsible for developing socio-economic business cases, particularly for enhancement projects. The main purpose of these business cases is to inform funding decisions. The LCC assessment usually considers only infrastructure options that deliver the socio-economic benefits in the business case. However, these benefits may vary between the infrastructure options. In such circumstances, the Sponsor should liaise with the Economic Analysis team to ensure that the business case captures the appropriate costs and benefits of each option

Risk and Value Management team

The Risk and Value Management team facilitates workshops during which the option selection decision is made – the option selection at GRIP stage 3 is undertaken at the value management workshop known as VM2. The results from the LCC assessment should be provided via the Sponsor in advance of the workshop taking place.

Safety, Technical and Engineering - Chief Engineer's team

The Professional Head roles under the Chief Engineer are responsible for developing and maintaining the Asset Policies and for making them available to project teams.

2.2.3 RACI table:

Table 1 - LCC RACI

LCC key activities	Sponsor	Project Manager	Programme Cost Planning Manager	Cost Planning Manager	WLC Team	Risk and Value team	RAM	DPE
LCC remit[4]	R	C	I	I	I	N/A	N/A	N/A
LCC specification and tools including asset information	A	R	C	C	C	N/A	N/A	N/A
Allocation of LCC resource	I	A	R	C	I	N/A	N/A	N/A
LCC assessment	C	A	C	R	C	I	C	C
Gathering of information about safety and sustainability for LCC report	C	R	I	A	C	N/A	C	C
Drafting of LCC report	C	C	A	R	C	I	C	C
Methodology, tools and life cycle data	N/A	C	C	A	R	N/A	N/A	N/A

[4] The Client is accountable for the LCC remit via the Client Requirements document.

2.2.4 RACI definitions:

Responsible

Those who do the work to achieve the task - typically one role, although others can be delegated to assist.

Accountable

The role/person required to approve the deliverables and to justify and evidence that the task has been correctly and thoroughly completed and who delegates the work to those responsible. An accountable person must sign off (approve) work that the responsible person provides.

Consulted

Those whose opinions are sought, typically subject matter experts, with whom there is a two-way communication.

Informed

Those who are kept up to date on progress, often only on completion of the task or deliverable; with whom there is just one-way communication.

3 RECOMMENDED LCC METHODS

3.1 General principles and definitions

Sections 3.2 and 3.3 provide guidance on the form of LCC analysis that is appropriate at GRIP stages 2 and 3 respectively. The intention of this manual is to provide Network Rail specific guidance on LCC to projects rather than describe the general principles of LCC which are adequately covered in text books, standards and application guides.

3.1.1 Real and nominal costs

The adjustment of cash flow costs for inflation, deflation and estimated efficiency or technological change results in a cash flow of costs at the amounts that are expected to be paid in the future. These future costs are referred to as nominal costs. Real costs are the costs current at the base date. For LCC analyses in Network Rail it is recommended that real costs are used (Ref. [3]).

3.1.2 Discounting, inflation and the time value of money

The time value of money refers to investment and price movements over time. Investments generally increase in value by a percentage rate of return. Alternatives or options are evaluated based on the notional return on the estimated investment, had the monetary amount been invested rather than expended on the option being considered (Ref. [3]).

Inflation is a rise in the general price level, reflecting a decline in the purchasing power of money. The rates of inflation for differing items are not constant. In general, manufactured high technology products tend to fall in price over time; fuel prices increase when the raw product becomes scarce, and labour prices tend to increase in line with productivity improvements (Ref. [3]).

Discounting is the process used to bring all future costs to a value at the base date. The percentage return used in LCC to bring such future costs to present day values is called the discount rate. For Network Rail the discount rate to be applied is determined by HM Treasury's Green Book:

Table 2 - Discount rates

Years	Discount rate
0-30	3.5%
31-75	3.0%
76-125	2.5%

3.1.3 Net Present Value (NPV)

Net present value is determined by calculating the cash flows for each period of an investment. The period is typically one year, but could be measured in quarter-years, half-years or months. After the cash flow for each period is calculated, the present value (PV) of each one is achieved by discounting its future value at a periodic rate of return (usually a rate of return dictated by the market but in Network Rail's case, that determined by HM Treasury's Green Book, above). NPV is the sum of all the discounted future cash flows. NPV is a central tool in discounted cash flow analysis and is a standard method for using the time value of money to appraise long-term projects.

Because of its simplicity, NPV is a useful tool to determine whether a project or investment will result in a net profit or a loss. A positive NPV results in a profit and a negative NPV in a loss. For Network Rail, profit is a net benefit to society and loss is a net loss to society and this would be determined in the socio-economic business case (see section 1.3.2).

In terms of LCC only costs and cost savings are included, as positive cash flows, so the lowest NPV (effectively net present cost) represents the best option.

3.1.4 Period of analysis

The time period over which the LCC is analysed, starting with the first project expenditures, and extending through the useful life of the project or its most long-lived alternative, or some future time at which meaningful estimates of effects are no longer possible.

Sometimes different alternatives include components having very different physical lifetimes. For example, rail vehicles and railways may give longer periods of service between replacement and reconstruction compared to buses and bus lanes. In these comparisons, the analysis time period should be long enough to capture the full life cycle of the longest-lived alternative with due consideration of residual values of components of other alternatives which may have undergone replacement or rehabilitation close to the end of the time period.

For the purposes of LCC analysis for projects within Network Rail it is recommended that the period of analysis is set at the shorter of 100 years, or two life cycles of the asset.

3.1.5 Annualised cost

Annualised cost is the total undiscounted cost for the period of analysis divided by the period of analysis. While discounting is technically correct it is more difficult to apply, particularly at GRIP stage 2, when this technique would more commonly be used. At this stage the intention is to look for big differences between options in order to reduce a long list to a short list and an option should not be ruled out due to the impact of discounting.

3.2 Recommended approach at GRIP stage 2

The starting point for the LCC assessment at GRIP stage 2 is a set of infrastructure options that have the potential to deliver the benefits forecast in the business case. The requirement to consider a range of options derives from GRIP rather than from LCC considerations. LCC determines the way in which options are compared, requiring a broader, longer-term view than is provided by the historically prevalent approach of seeking the lowest capital construction cost.

At GRIP stage 2, the objective is to use established decision making criteria e.g. Asset Policies, to identify the lowest life cycle option or, alternatively, to apply a qualitative (or part quantified) approach to reducing the number of options that require a detailed analysis at GRIP stage 3.

The guidance below summarises the key steps required in the analysis. It also provides guidance on the interpretation of the results and how recommendations on option selection should be taken forward to GRIP stage 3.

Analysis

1. Clarify the scope of the various infrastructure options necessary to deliver the outputs e.g. for train lengthening projects, the options could involve platform lengthening or selective door opening. The preference would be to establish a base case which would represent 'do-nothing' although it is accepted that this is not always desirable or practicable.

2. Obtain the Cost Plan for implementing each option (acquisition and installation costs). These would usually be the GRIP stage 1 Cost Plan AFCs because the GRIP stage 2 Cost Plan AFCs will be developed subsequently. At GRIP stage 1, the AFC is the Point Estimate (Base Cost) plus a risk allowance of 60%; at GRIP stage 2 the risk allowance is 40%.

3. Confirm the assumed business case benefits apply equally to each option. If not, document any differences.

4. The key steps in the process are outlined below and would usually be addressed through a workshop with a relevant panel of experts[5].

   a. Review the Asset Policies for the relevant asset disciplines (11 in total) and, where they are sufficiently prescriptive, apply them to select the appropriate option.

   b. Where the Asset Policies are not sufficiently prescriptive, check whether a precedent exists in which the lowest LCC solution has been established for a similar project. If so, use the precedent to select the appropriate option. A library of previous LCC assessments is available to access via the LCC page on Connect[6].

   c. If neither of the above two option selection criteria apply, it is necessary to go a step further in comparing the alternatives. It is recommended that a semi-quantitative approach is adopted, using Table 3 below, or an adaptation of it given that most projects will have features that can't be accommodated in a rigid template. Completion of the table requires the following steps:

      i. Insert the GRIP stage 1 Cost Plan AFC in the installation column for each option.

      ii. For other cost components, identify where the costs are the same for all options and do not consider them further in the analysis.

      iii. For safety risk and environmental impact, it is appropriate at this stage to provide qualitative comparisons. The monetised costs for these components are likely to be low, but it is important to identify where there are differences between the components. It is sufficient at this stage to record whether the options have a negative, positive or neutral impact relative to the base case.

      iv. Where there is a material difference between the cost components for each option, i.e. it could affect the option selection decision, determine whether the cost for each option is Very high (VH), High (H), Medium (M), Low (L) or Negligible (N).

      v. These category definitions are at the discretion of the project but, as a guide, it is recommended that they are (a) monetised to provide consistency across categories; and (b) expressed as a percentage of the average installation cost across all options e.g.

         - Very high: Annualised cost > 5% of the average installation cost
         - High: 1% < Annualised cost ≤ 5%
         - Medium: 0.1% < Annualised cost ≤ 1%
         - Low: Annualised cost ≤ 0.1%
         - Negligible: Annualised cost ≈ 0

[5] In practice it may be easier to perform steps (a) and/or (b) before the workshop
[6] http://connect/communities/LifeCycleCosting/default.aspx

Table 3 - Template for GRIP stage 2 option comparison

Option	Installation cost (£)	Annualised cost (VH, H, M, L, N)							Qualitative	
		Inspection	Planned maintenance	Reactive maintenance	Operations	Service risk	Renewal	Disposal	Safety risk	Environmental impact
Base case	GRIP stage 1 Cost Plan AFC									
Option A	GRIP stage 1 Cost Plan AFC									
Option B	GRIP stage 1 Cost Plan AFC									
Option C	GRIP stage 1 Cost Plan AFC									
Etc.										

3.2.1 Interpretation of results and proposed LCC option

When Table 3, or equivalent, has been completed, it may be that one option clearly represents the lowest LCC. Alternatively there may be several options with broadly comparable life cycle costs. In the case of the former, the LCC input to the option selection process is complete. LCC is one of the factors that influence the final option selection decision, so the LCC results for all options should be made available to the VM2 workshop at GRIP stage 3.

In the case where a number of options have similar life cycle costs, they should form a shortlist for further analysis during GRIP stage 3. In all cases it is necessary to record differences in safety risks and environmental impacts as they may be given additional weighting in the final option selection.

As stated above, the analysis will generally be based on GRIP stage 1 Cost Plan AFCs. The validity of the conclusions should be sense checked when the GRIP stage 2 Cost Plan AFCs become available.

3.3 Recommended approach at GRIP stage 3

The input to the GRIP stage 3 assessment is a shortlist of options identified during GRIP stage 2. The shortlist contains options that have similar orders of magnitude for the total life cycle costs, which means that a more detailed quantitative assessment is required.

A process for analysing and evaluating the life cycle costs for options at GRIP stage 3 has been used in several projects and remains suitable for future application. It has 11 steps which are outlined below:

Step 1: Provide context for the LCC assessment

This should be simply an extract from existing project descriptions, providing an overview of the project's aims and objectives. It should also highlight previous work, such as the LCC analysis undertaken at GRIP stage 2.

Step 2: Describe the project options

Similarly, the infrastructure options will usually have been identified previously, although there may be changes in the scope or in the business case assumptions that need updating. It is important at this stage to align the options with the business case outputs and to reconcile any differences so that comparisons can be made on a like-for-like basis.

Step 3: Establish the level of LCC analysis required, define the period of analysis

The level of quantification required in the analysis is that which is sufficient to differentiate the life cycle costs of the remaining options i.e. it is still a comparative analysis at this stage. However, a higher degree of rigour is needed than in GRIP stage 2 and it is recommended that in most cases Network Rail's generic LCC model, Cost Benefit Asset Lifecycle Tool (CoBALT) is used (Section 4).

It is also necessary at this stage to define the period of analysis i.e. the duration over which the life cycle costs are calculated. This can vary by project and should take account of the nominal life of the assets, the period over which benefits are accrued and the potential for further changes in the future (Section 3.1.4).

Step 4: Describe the asset configurations

This stage should identify the assets being introduced by the project and the existing assets that may be affected. It is also necessary to specify the interactions between assets that may have an impact on the life cycle cost. An asset inventory should be compiled at this stage with information, as appropriate, on asset types, location, installation dates (proposed, or actual for existing assets), condition, key interfaces etc. The structure of the asset inventory should align with the asset hierarchies provided in the Asset Lifecycle Profile (ALP) Catalogue (see Step 6 below).

Step 5: Obtain acquisition and installation costs

The analysis should assume the GRIP stage 2 Cost Plan AFCs as they will not have been further developed during the option selection phase of GRIP stage 3. Any refinements that can be easily made should be implemented.

Step 6: Obtain through-life costs

These relate to the costs that are incurred after the project is developed, designed and delivered, and the assets become operational. Through-life costs include the tangible costs associated with inspection, maintenance, operations e.g. energy costs, and renewal. They also include the costs associated with assets failing to meet their intended purpose, which could include train delay penalties, safety risks and environmental impacts.

This information has traditionally been difficult to obtain. However recent and ongoing work has created a library of such information for the most common types of assets on the network which is available to projects in the form of ALPs. The assets available in this form are listed in the ALP Catalogue, which is available on the LCC page on Connect[7] (Section 4.3).

Step 7: Calculate the life cycle costs

Prior to this stage, information will have been collated on the assets associated with each option, the costs of acquisition and installation of these assets as represented by the Cost Plan AFC and their through-life costs. This stage is effectively an aggregation over all the assets within the scope, year by year, over the defined period of analysis. The CoBALT model provides a straightforward way of performing such calculations and for ensuring consistency within and across different projects (Section 4). A standard set of graphs and reports is provided at this stage including a comparison of NPVs, discounted and undiscounted cash flows.

[7] http://connect/communities/LifeCycleCosting/default.aspx

Step 8: Compare safety risks

The monetised value of safety risks over the life of a project is usually small compared with the costs of installation and maintenance, except where the investment is targeting a safety improvement e.g. through level crossing closures. This step has been included to raise the profile of safety considerations. For example it may not be deemed acceptable to select an option that has a higher safety risk even if it has a lower life cycle cost.

Where projects introduce a significant technological, operational or organisational change to the railway system the application of the CSM requires a demonstration that the risks resulting from the change are as low as reasonably practicable. The application of the CSM is a separate process but this step is an appropriate point at which economic and safety aspects should be considered together. For example there may be an opportunity to identify safety improvements which could be potentially introduced for a small incremental cost.

Step 9: Assess sustainability improvements

As with safety, it is possible for the life cycle costs to mask potential improvements that may reduce the environmental impact or deliver other sustainability benefits. The identification of such improvements will usually be undertaken in a separate workstream, but inclusion in the LCC appraisal enables their consideration alongside other factors which affect life cycle performance. Some of the factors that should be included are:

- Vegetation and habitats
- Carbon emissions or embedded carbon
- Material selection
- Hazardous materials
- Weather resilience
- Community impact

The STE - Environment and Sustainability team can provide access to several tools to quantify the sustainability impact including the costs of embedded carbon.

Step 10: Analyse sensitivity and uncertainty

As described above, the acquisition and installation costs will have a significant uncertainty (a Risk Allowance of 40% is applicable at GRIP stage 2, which should be validated by the Risk and Value Team) and other parameters will typically be even more uncertain. In addition there will be a number of assumptions that are also uncertain which could have a significant impact on LCC. It is necessary therefore to analyse the effects of these uncertainties, usually by undertaking sensitivity analysis in which factors or combinations of factors are changed and the impact assessed.

Step 11: Evaluate the results and propose the lowest LCC option

The aim of the final step is to review the results from the analysis and to propose the option that best represents the lowest life cycle cost. The conclusions should take account of the uncertainties and other factors that aren’t monetised. All calculations should be checked and the results peer reviewed. The Programme Cost Planning Manager will arrange for the peer review, which would usually be undertaken by another member of the Cost Planning team not directly involved in the analysis.

4 SUPPORTING TOOLS AND INFORMATION

4.1 Overview

To support the growth in demand for LCC assessments since it was formally mandated in April 2014, it was recognised that there was a need to provide a standard generic model for LCC, a set of standard assumptions (default parameters), and a repository for accessing through-life information. These are described in the following sections. Guidance on the practical application of the tools and information at GRIP stages 2 and 3 is also provided.

4.2 Generic LCC model - CoBALT

The Cost Benefit Asset Lifecycle Tool (CoBALT) is Network Rail's generic model for performing LCC calculations. It is conceptually a straightforward model, requiring information about the asset or assets under consideration, and projecting forward in time to calculate the costs incurred in each year over the period of analysis.

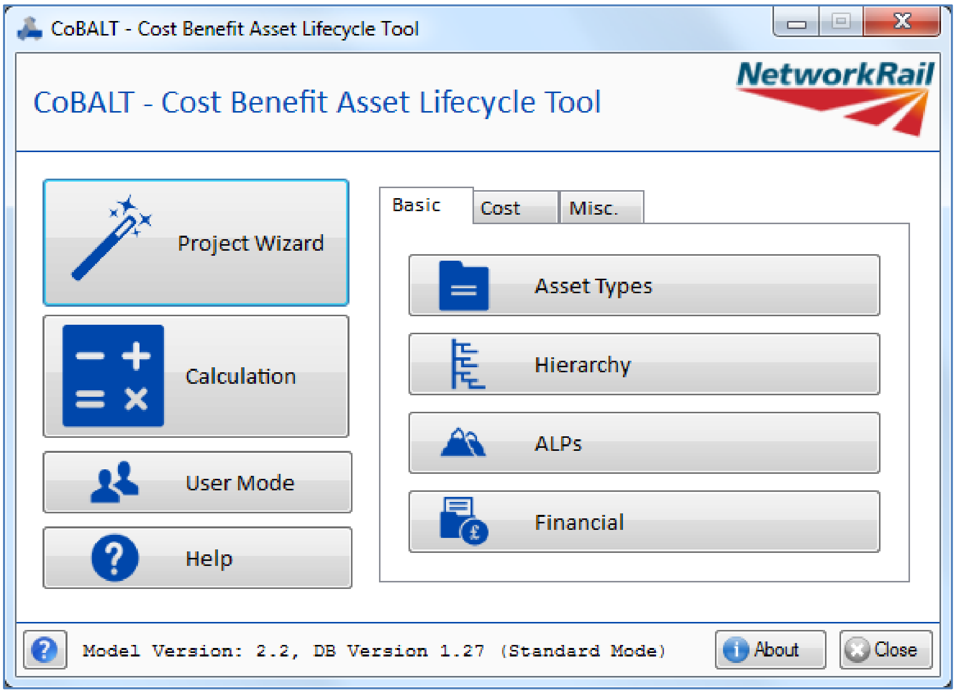

Figure 4 – Introductory screen for CoBALT

The WLC team is responsible for developing, maintaining and updating the model and for providing training on its application. CoBALT is available to download via the IT Software Catalogue on Connect, but, while regular refinements are being made, a request to the WLC team is the preferred means of obtaining a copy (LifeCycleCosting@networkrail.co.uk).

The CoBALT user guide is integrated with the model and can be accessed interactively while using it. An extract from these documents, highlighting the key inputs, default parameters and outputs is provided below.

<u>User-defined inputs</u>

CoBALT has been designed to minimise the work involved in setting up and running a LCC calculation by limiting the inputs to those which only the user is able to define (e.g. input by the Cost Planning Manager from the information detailed in the Cost Plan Request form). Other inputs are either set as default parameters in the model (see below) or available from a central repository.

- Asset types and configuration: The user is required to define the assets and, where appropriate, the sub-assets in the form of a parent-child asset hierarchy.
- Installation date: The date at which the asset was installed (for existing assets) or the date of commissioning for new assets.
- Installation cost: The most recent Cost Plan AFC for the installation cost e.g. the GRIP stage 2 Cost Plan AFC.
- Through life costs: Annual costs for inspection, planned maintenance, reactive maintenance, operations, renewals, train service impacts, safety risk. These are usually obtained from the ALPs described in Section 4.3 below.
- Period of analysis: The duration over which the LCC calculation is to be performed.
- Base year: The year from which the calculation begins. This is the year from which a difference in assets or their profiles occurs.

<u>Default parameters</u>

CoBALT contains a small number of parameters which are set as defaults. They can be modified by the user (e.g. by the Cost Planning Manager on the instruction of the Sponsor) but are consistent with Network Rail policy and would be changed by exception or to test sensitivity.

- Discount rates: Default values are consistent with HM Treasury's Green Book i.e. 3.5% (1-30 years), 3% (31-75 years), 2.5% (76-125 years). The discounted and undiscounted results can be viewed in the output report.
- Value for Preventing an Equivalent Fatality (VPF): In order to monetise safety risk, it is necessary to assign a VPF. The default value is consistent with Network Rail's Safety Management System and is updated annually.

<u>Key outputs</u>

CoBALT provides a number of standard graphs and tables, as well as a dataset for interrogating detailed aspects of the calculations. The two most commonly referenced outputs for comparing options are:

Net Present Value*:* The sum of all costs over the period of analysis for the option under consideration, adjusted for the time value of money. The costs incurred in each year are discounted using the rates referred to above, so that all costs represent the value at the start of the analysis period.

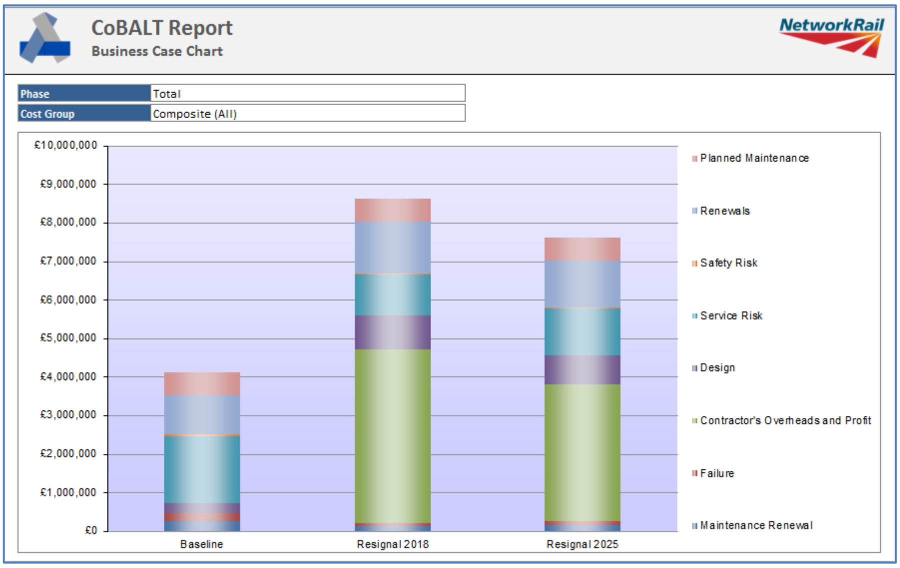

Figure 5 – Example of CoBALT output comparing NPVs for three options

Cumulative Cash Flow*:* For each year of the calculation, the costs are added to those incurred in the previous year. For the final year of the analysis period, the cumulative value is equivalent to the NPV. It is also possible to view the cumulative cash flow without discounting.

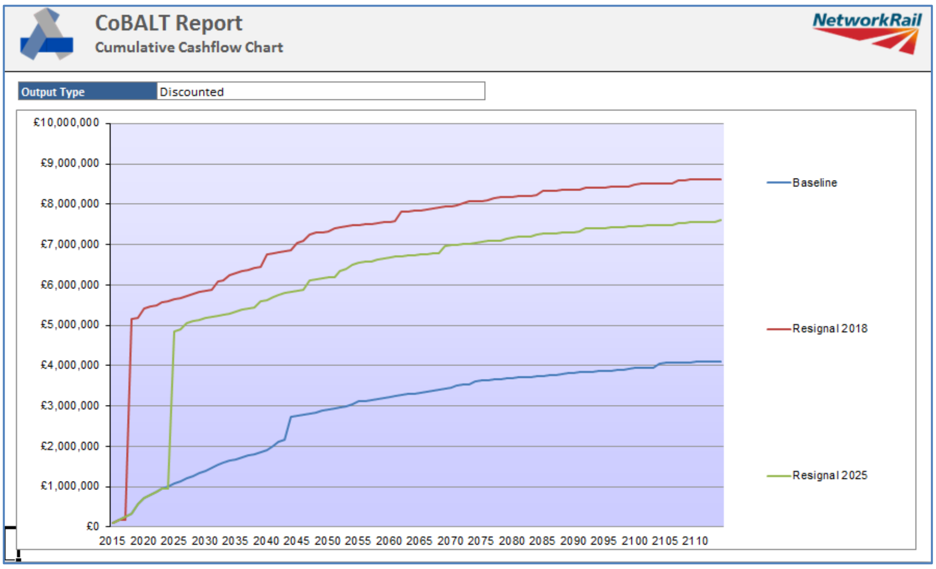

Figure 6 – Example of CoBALT output comparing cumulative cash flows for three options

4.3 Asset Lifecycle Profiles

The most difficult challenge in conducting a LCC assessment is obtaining the in-service costs over the operational phase of the life cycle e.g. inspection, maintenance, cost of asset failure etc. This is mainly because the costs have not been systematically analysed in the past and local factors have a significant influence e.g. traffic density, track access etc.

In order to address this gap, an initiative has been undertaken to compile a 'library' of through-life cost information for critical infrastructure assets i.e. the assets that have the biggest impact in terms of maintenance expenditure, train performance and system safety. A common template was derived so that the through-life costs would be in the same format for all asset types and the templates could be directly input to the CoBALT model.

The populated templates are known as ALPs. They are stored as Excel spreadsheets. They have been produced mainly by running asset specific models in which the through-life costs can be calculated. Table 4 below shows the asset disciplines for which ALPs have been produced. For each asset discipline there will be a number of sub-assets e.g. overhead line equipment comprises the registration arm, catenary wire etc. For each asset type there will be different permutations of ALPs to reflect operational characteristics e.g. train usage patterns, and to reflect different intervention strategies e.g. one for a refurbishment strategy, another for conventional renewal. The table shows the key variables that require different ALPs to be generated. It also lists the main cost categories that are included in the ALPs. The costs are provided annually, typically over a 100 year period.

Table 4 - Asset disciplines

Asset discipline	ALP permutations due to different cost drivers	Key cost categories stored in ALPs
• Track • Signalling • Bridges • Operational Property • Earthworks • Electrical Power	• Usage e.g. gross tonnage • Route criticality • Intervention strategy e.g. refurbishment	• Inspection • Planned maintenance • Reactive maintenance • Refurbishment • Renewal (including disposal) • Service risk (i.e. Schedule 8) • Safety risk (Fatalities and Weighted Injuries, FWI)

An example of a specific ALP is provided in Appendix C. There are currently several thousand ALPs covering the range of asset types and cost drivers listed above. The ALPs will be provided via a self-service system solution during 2017. Until this is available, the relevant ALPs can be selected from the ALP Catalogue on the LCC page on Connect[8] and requested from the WLC team (LifeCycleCosting@networkrail.co.uk) following the process shown in Appendix B.

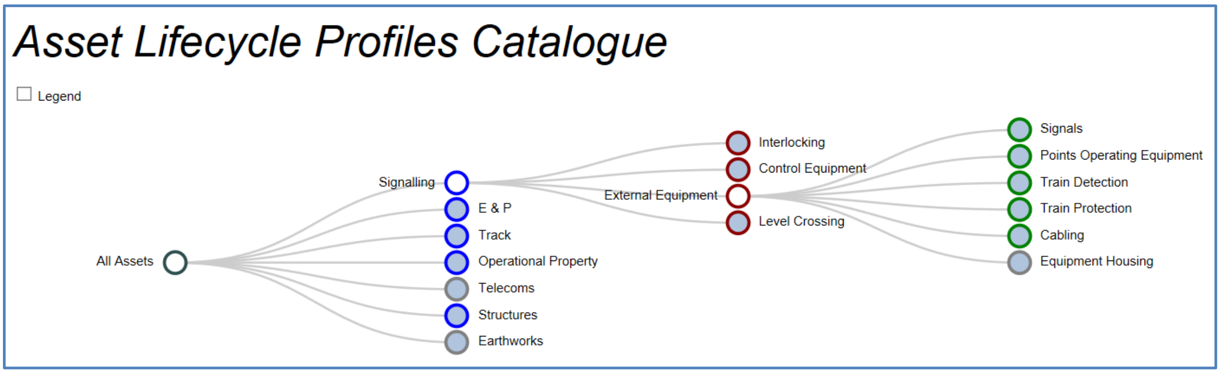

Figure 7 - Extract from the ALP catalogue

The format of the ALPs allows the through-life cost information to be automatically uploaded into CoBALT. The ALPs can also be used standalone without using CoBALT, for example to compare the life cycle costs of different asset types. Guidance on the practical application of the ALPs at GRIP stages 2 and 3 is provided below.

4.4 Practical application at GRIP stage 2

As discussed in Section 2, the LCC objective at GRIP stage 2 is intended to reduce the number of options taken forward to GRIP stage 3 by undertaking a comparative analysis of options based largely on qualitative arguments supported by indicative costings.

A quantified analysis using CoBALT is not expected at GRIP stage 2. Instead, the ALPs could be used to provide most of the information required to populate Table 3 (page 17). For example, a capacity improvement programme on a specific route section may have multiple options for delivering the required benefits, with different asset configurations having the potential for delivering the required business benefits. In such cases, the recommended approach would be to estimate the costs of

[8] http://connect/communities/LifeCycleCosting/default.aspx

managing the route section before the enhancement (the base case) and then consider the impact of applying the different infrastructure options. A simple way of generating the life cycle costs would be as follows:

- To create a base case, establish the counts for each asset type for the route section before the enhancement.
- Extract the average annual cost for each asset type from the relevant ALPs.
- Estimate the total annualised cost for the route section as the sum product of the asset counts and annualised costs.
- Create the equivalent asset inventory for the first enhancement option and assign the average annual costs from the ALPs to calculate an average annual cost for the route section.
- Repeat the above step for the other options
- Enter the results in Table 3 - Template for GRIP stage 2 option comparison

There are other ways of using the ALPs at GRIP stage 2 but the general principle will always be to combine the assets under consideration with cost extracts from the ALPs to provide comparative LCC estimates.

4.5 Practical application at GRIP stage 3

The level of quantification required at GRIP stage 3 will usually require the application of CoBALT with the associated ALPs. The 11-step process for undertaking a LCC assessment is described in Section 3.3. Modelling issues need to be considered at each step of the process, although setting up and running the model is concentrated in the steps listed below. The outline provided below is intended to show that the model is very straightforward to apply when the input data is available.

<u>Step 4: Describe the asset configurations.</u>

In this step, the asset hierarchies for each option are specified together with installation dates, and input to CoBALT, as detailed in the Cost Plan Request form.

<u>Step 5: Obtain acquisition and installation costs</u>

Where new assets are to be installed as part of the project the cost of acquisition and installation is input by the user into CoBALT. The costs should be obtained from the GRIP stage 2 Cost Plan AFCs.

<u>Step 6: Obtain through-life costs</u>

In the majority of cases, this will simply involve the identification of the relevant ALPs (by the Project Manager) and assigning them to the corresponding assets in CoBALT (by the Cost Planning Manager). In some cases it may be necessary to create a new ALP from scratch e.g. when considering a novel asset type. In such cases, completing the fields in the ALP template will enable the through-life costs to be added in the same way as for the established assets. The WLC team (LifeCycleCosting@networkrail.co.uk) will provide support for the creation of novel ALPs.

<u>Step 7: Calculate the life cycle costs</u>

At this stage, the user (the Cost Planning Manager using the values agreed in the Cost Plan Request form) specifies the period of analysis and initiates the calculation in CoBALT. A standard set of reports is produced, including NPV charts and Cumulative Cash Flows. The CoBALT inputs and default parameter settings are also documented to provide a record of the assumptions.

<u>Step 10: Analyse sensitivity and uncertainty</u>

The functionality to enable uncertainty analysis is being developed and is therefore not currently available. Until this has been provided, CoBALT can be run a number of times with adjustment to inputs or to default parameters to estimate the impact of uncertainties in data and assumptions on the key outputs.

5 RECORDS AND ASSURANCE OF LCC ASSESSMENTS

5.1 GRIP stage 2

The following documentation should be provided to stakeholders (including the roles referenced in the RACI in Section 2.2) at the end of GRIP stage 2.

- Copy of the Sponsor's remit
- Copy of the Project Manager's instruction
- Copy of the completed Cost Plan Request form
- Report of the LCC assessment consistent with the process in Section 3.2
- A recommended LCC option or a shortlist of options to be considered in GRIP stage 3

5.2 GRIP stage 3

The following documentation should be provided to stakeholders (including the roles referenced in the RACI in Section 2.2) at the end of GRIP stage 3.

- Copy of the Sponsor's remit
- Copy of the Project Manager's instruction
- Copy of the completed Cost Plan Request form
- Report of the LCC assessment consistent with the 11 step process described in Section 3.3
- A summary of the LCC conclusions for consideration in the option selection workshop (VM2)

6 FURTHER INFORMATION

6.1 Information

Further information and resources on LCC within Network Rail can be found on the Connect page (http://connect/communities/LifeCycleCosting/default.aspx).

The page contains links to the Cost Plan Request form, ALP catalogue and ALP guidelines.

6.2 Training

There are two LCC training courses available within Network Rail:

- ‘Life Cycle Costing in Infrastructure Projects’ is a one-day course on the principles of LCC and LCC process within Network Rail. This is bookable via Oracle E-Business Suite and is aimed at all roles partaking in the collaborative process described within this manual.
- The second is a two-day practitioner workshop, primarily aimed at Programme Cost Planning Managers and Cost Planning Managers. The course is bookable by contacting the LCC mailbox: LifeCycleCosting@networkrail.co.uk

6.3 Support

For further support please contact the LCC mailbox: LifeCycleCosting@networkrail.co.uk.

7 WORKS CITED

[1] IEC, “BS EN 60300-3-3,” 1999.

[2] IEC, “Draft EN 60300-3-3 Ed.3,” 2015.

[3] RICS guidance note, “Life cycle costing - 1st edition,” Royal Institute of Chartered Surveyors, UK, 2016.

Appendix A PROCESS MAPS

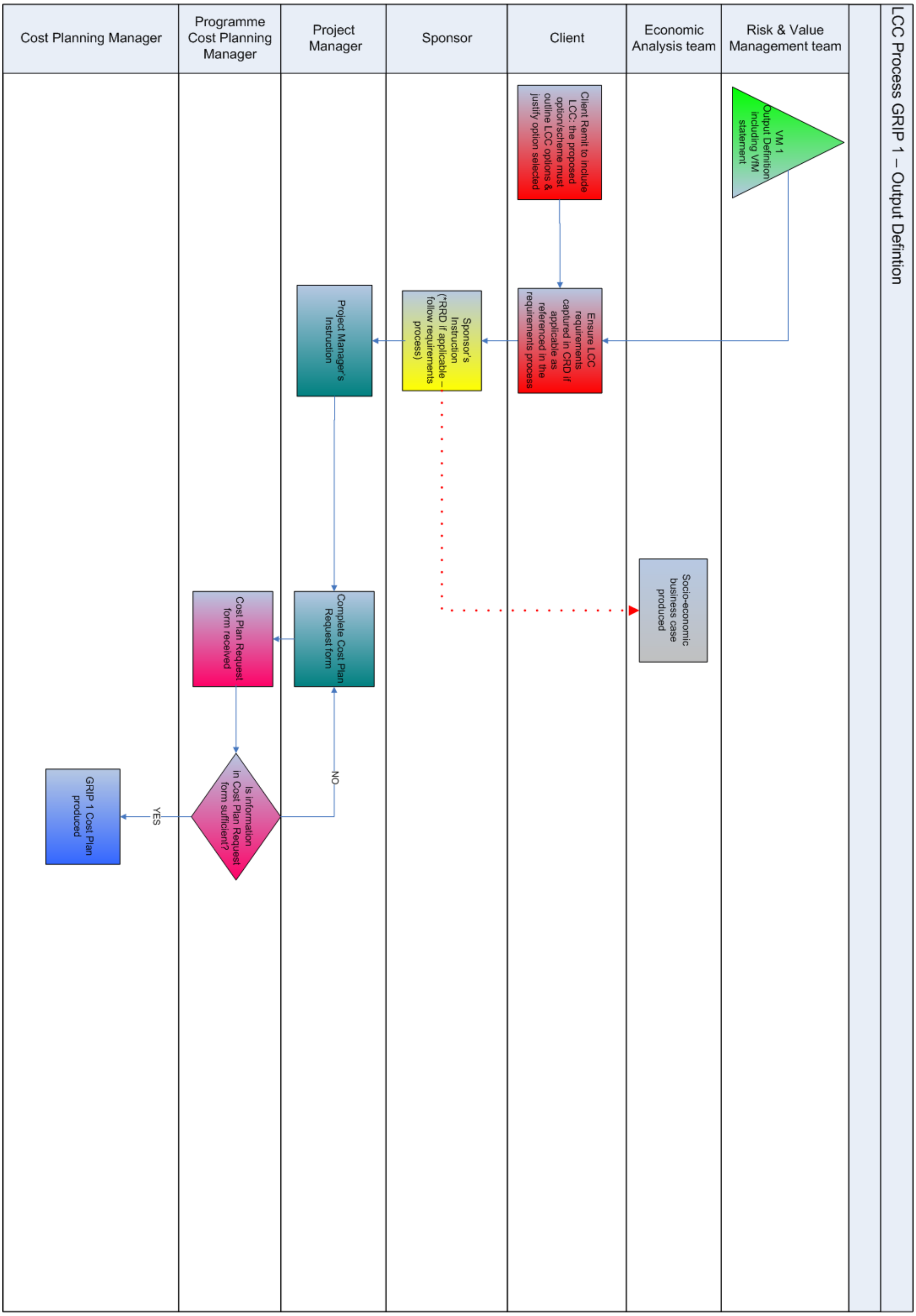

Figure 8 – LCC process map for GRIP stage 1

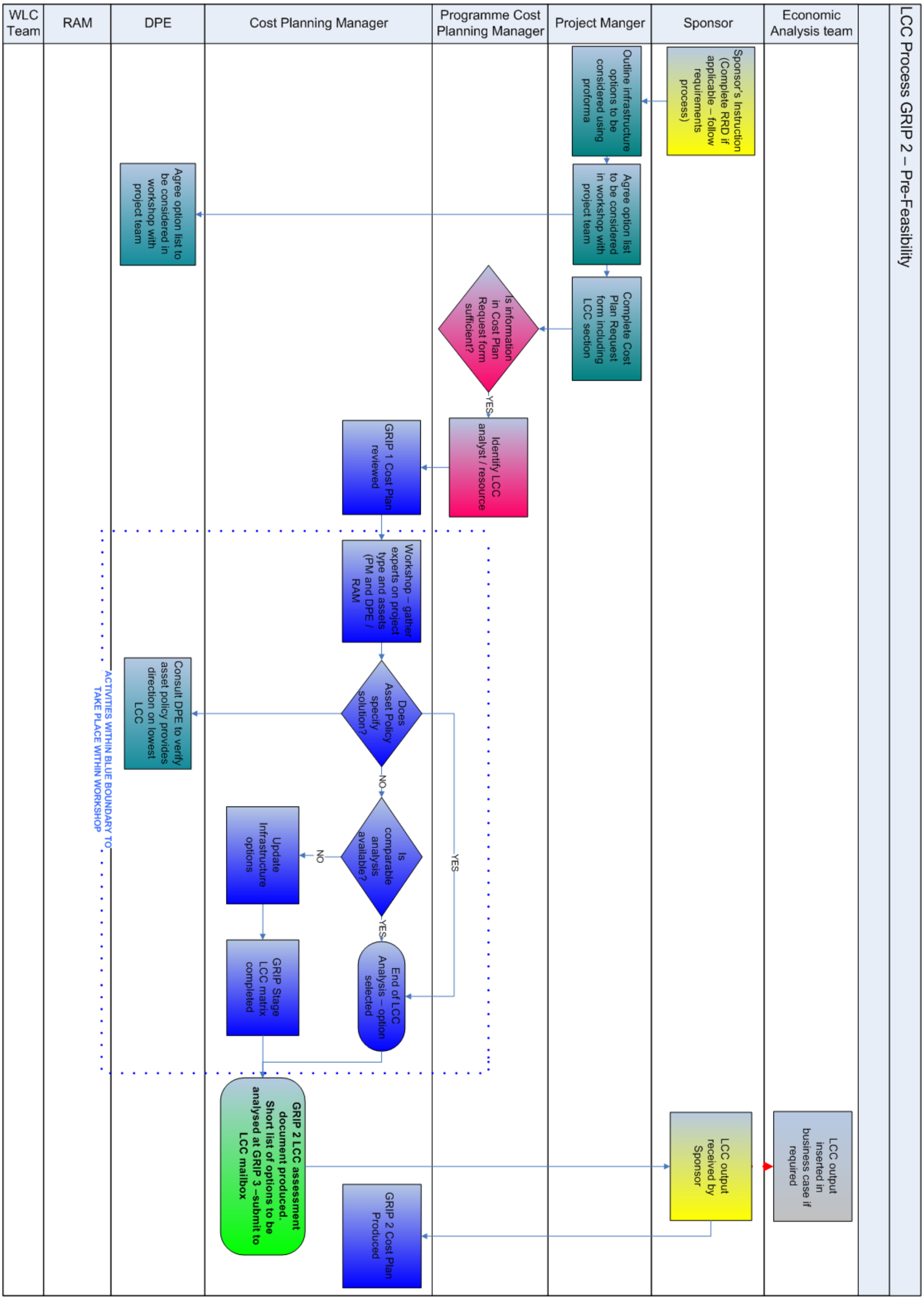

Figure 9 – LCC process map for GRIP stage 2

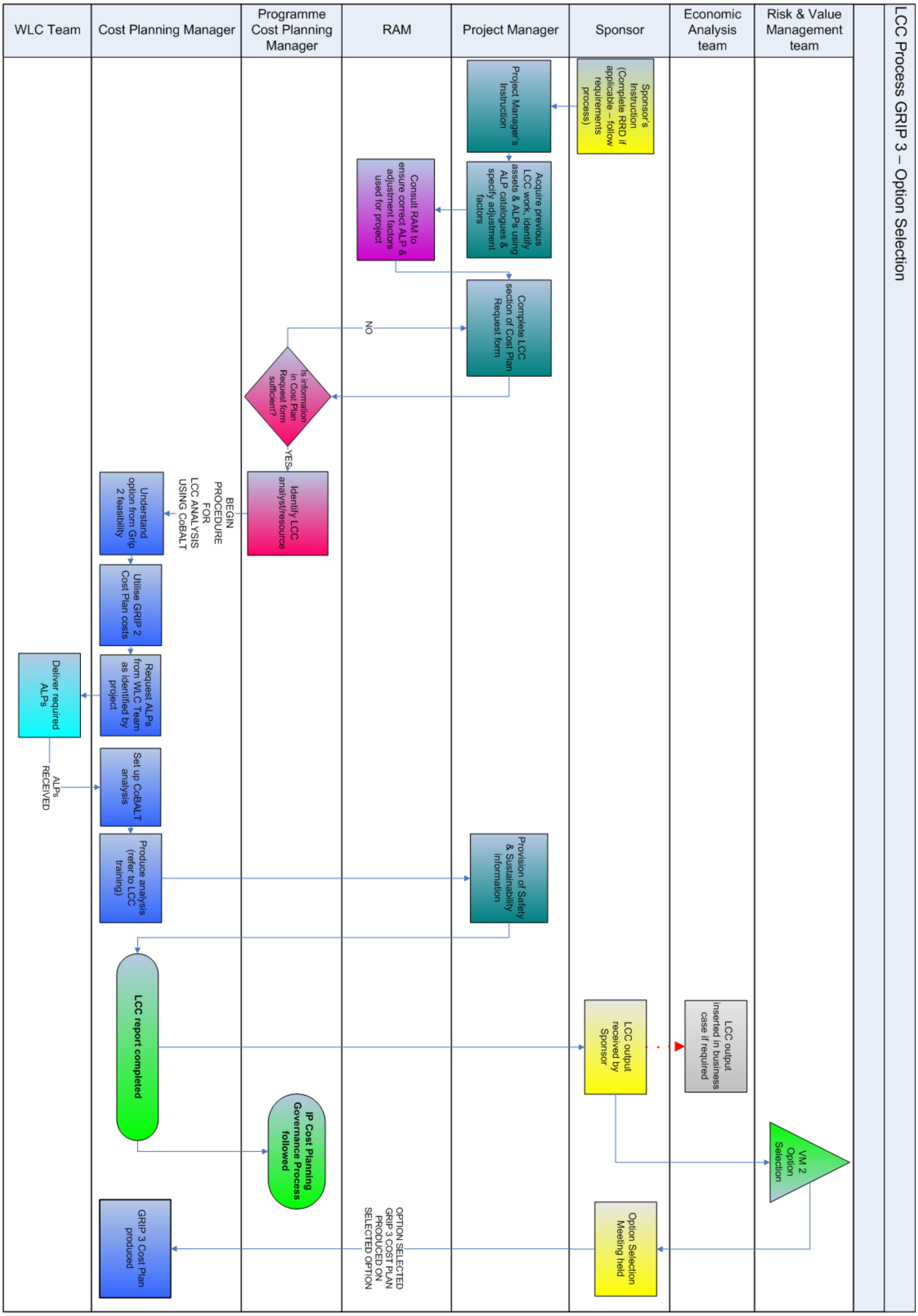

Figure 10 – LCC process map for GRIP stage 3

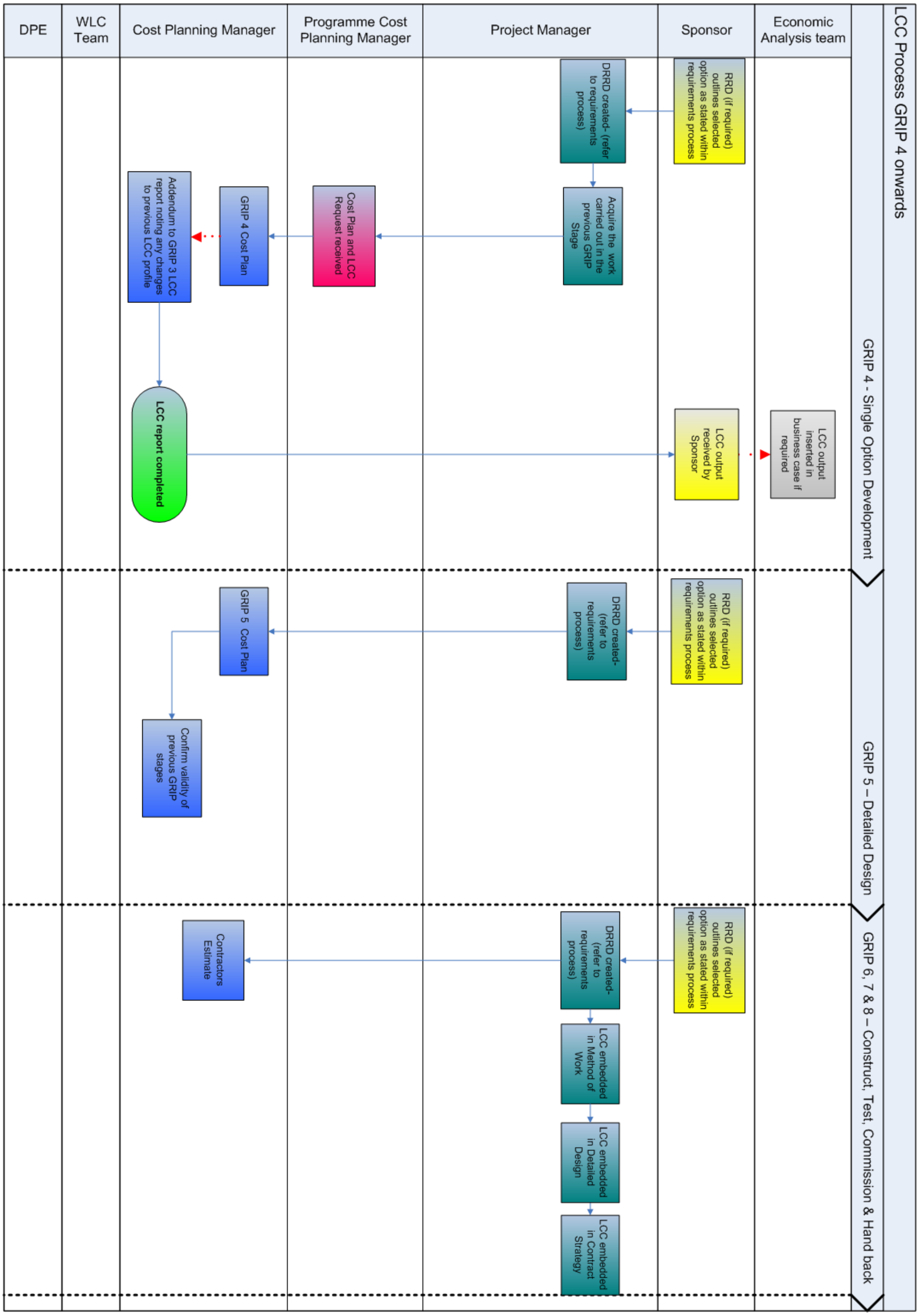

Figure 11 – LCC process map for GRIP stage 4 onwards

Appendix B ALP REQUEST PROCESS

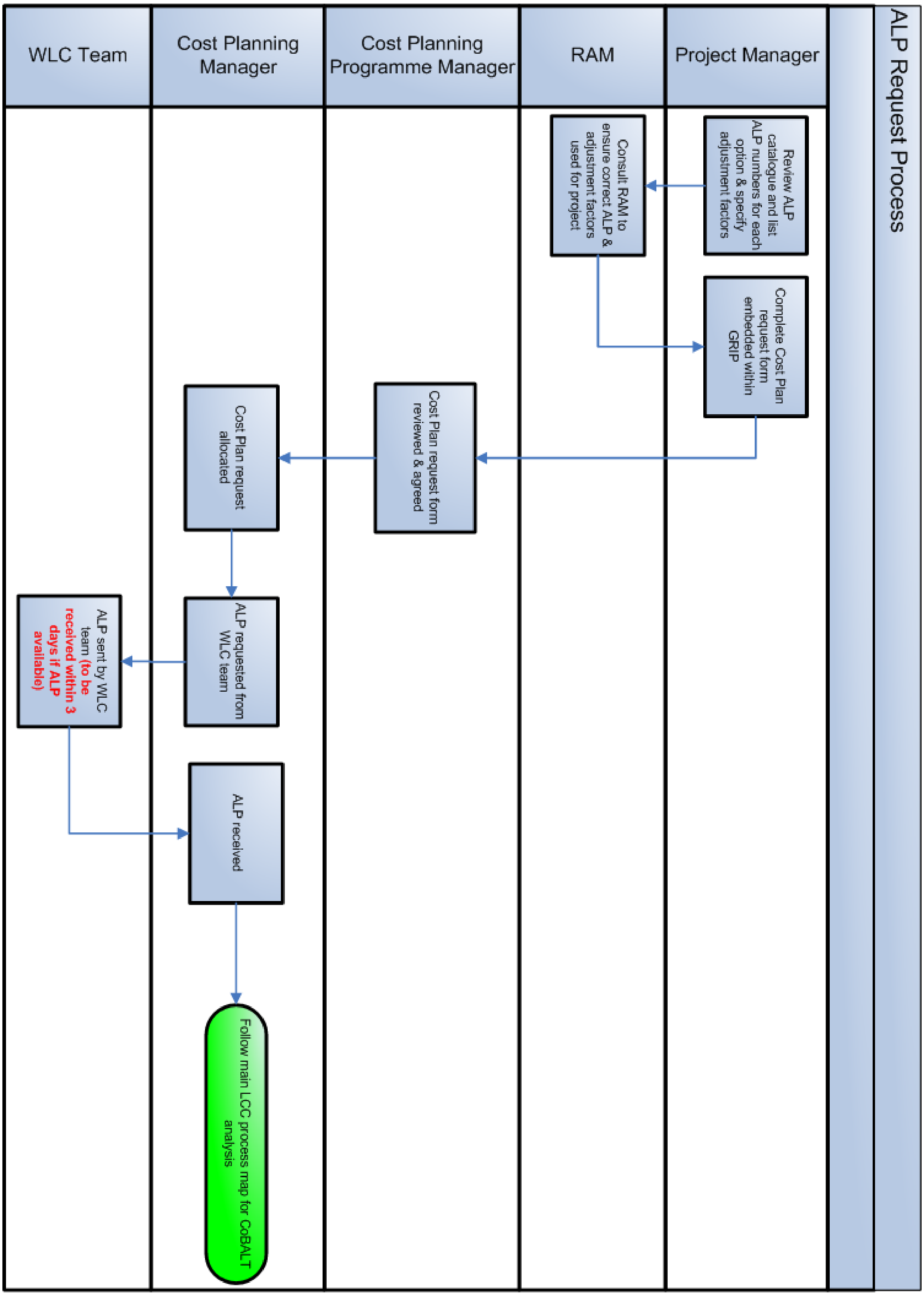

Figure 12 – ALP request process

Appendix C EXAMPLE ASSET LIFECYCLE PROFILE

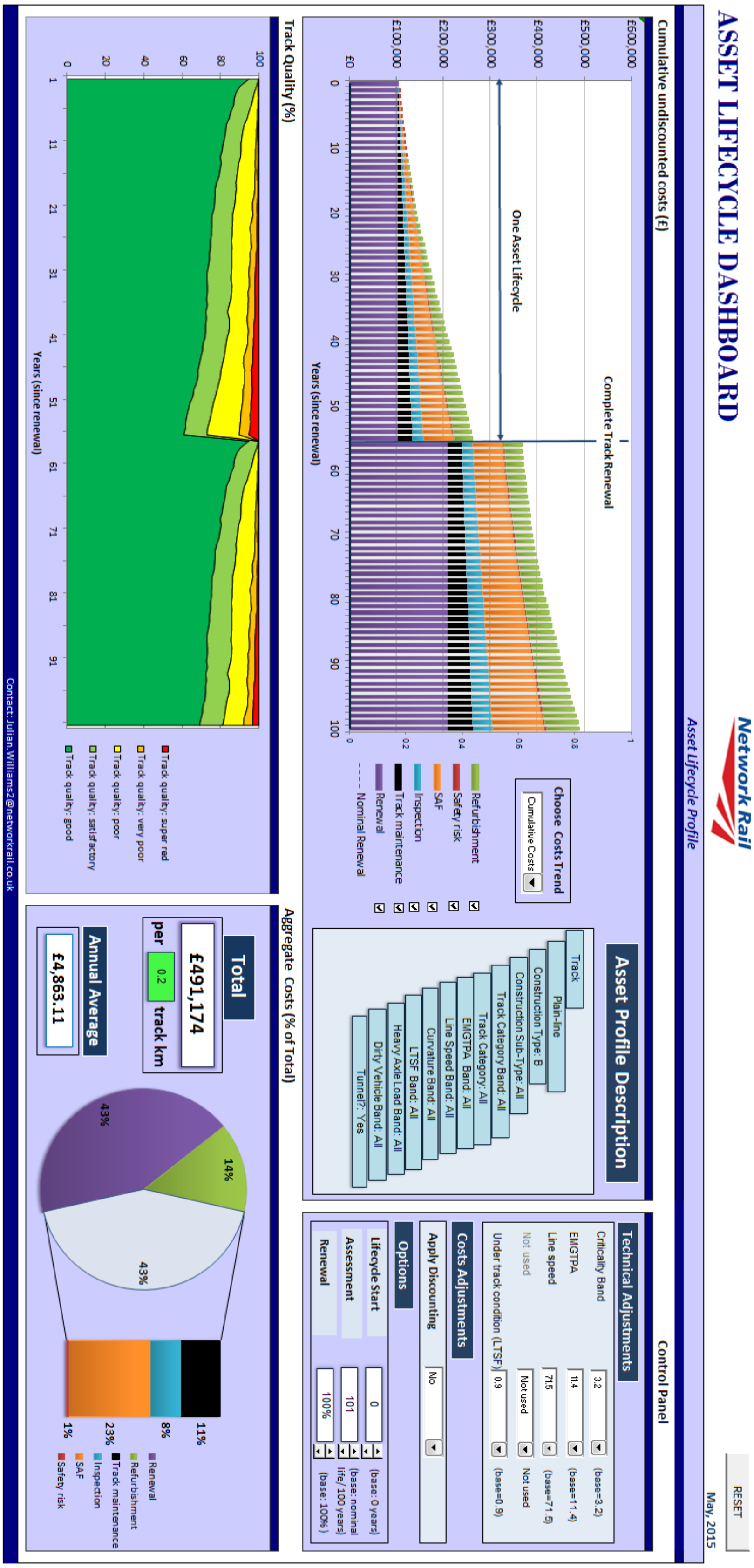

Figure 13 – Interactive dashboard for a plain line track ALP