Cross-industry Remote Condition Monitoring and Data Sharing - Business Case Guidance

I RESEARCH AND DEVELOPMENT

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Written by: Chris Charlwood, Asset Management Consulting Limited

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Cross-industry remote condition monitoring programme: Phase 2
RCM business case guidance

1 Introduction and aims

The rail industry faces a time of challenge and opportunity following the publication of the study 'Realising the Potential of GB Rail' in May 2011. Following that study there is a renewed focus on delivering a more effective and efficient railway, with closer alignment of train operations and infrastructure. The study identified the importance of improved asset condition information to support informed asset management decisions and deliver improved levels of service (such as reliability or maintenance efficiency). The industry is already trying to move from an 'observe and react' approach to failures to a more pro-active 'predict and prevent' approach.

The advent of hardware and software systems that can capture and process asset condition data in real-time, without manual input from an operator, generally termed remote condition monitoring (RCM), brings a real opportunity to achieve this. However, the success of these systems and the effective and efficient use of the associated data in the rail industry will be reliant on targeting the areas where substantial benefits can be achieved. This will be through cost-effective implementation, building upon existing systems where possible.

In 2012 the Rail Safety and Standards Board (RSSB) produced an RCM Toolkit to support users in developing a quantified business case for RCM equipment as part of the T857 project[1]; this toolkit includes a Decision Support Tool, a user guide and a series of industry case studies. In 2014, Asset Management Consulting Limited (AMCL) were commissioned to further develop the Toolkit and produce a guidance document on the development of business cases.

This document provides guidance to users on the principles that need to be considered when developing a business case for RCM, and also explains the general rationale and principles behind business cases and how they are used to justify investment.

The document complements the RSSB RCM Toolkit but also enables users to proceed without the Toolkit, where appropriate, and is to be read in conjunction with the User Guide for the 'RCM assessment toolkit', produced as part of the T857 project, and the revised RCM Toolkit developed by AMCL for the current work package T1010-04.

1 Relevant document for T857 project is available at the following link (free website account required to view document): http://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=9911

The RCM Toolkit developed by AMCL is designed for evaluating industry business cases for adoption or extending the use of RCM technologies. The level of detail is therefore based on what is required for a 'first pass' business case to evaluate system-wide costs and benefits for the industry, with some indication of likely implementation periods for these. It is expected that any business cases would be further developed by the individual parties involved to inform investment decisions. This would require further evaluation through company-specific investment processes supported by further refinement of the Toolkit outputs.

2 Business case theory

2.1 Introduction

The purpose of any business case is to capture the reasoning for initiating a project or task and it should adequately capture both the quantifiable and unquantifiable benefits and costs of a proposed project. Its purpose is to explain to decision makers why a project is worth doing over other competing projects that require resources.

Considering the 'do nothing' option is essential. This can be the best course of action and is useful as a baseline against all other options proposed.

2.2 Basic structure

A business case is typically broken down into the following sections:

1 Executive summary - brief, high-level summary of the whole document.

2 Introduction/Background - background to the project, including brief history and context (why was the project instigated and what is the scope).

3 Summary of Needs and Issues - all needs and issues requiring resolution, and/or business drivers for the project.

4 Options Appraisal - a detailed review of all of the options available, including an analysis of the benefits to be realised, risks (including those being mitigated) and costs of these options including whole life cost (WLC). This should also consider the 'do nothing' scenario.

5 Recommendations - identification of the preferred option with detailed justification.

6 Conclusion - summary of the options, recommendations, and next steps; including timescales, resources, and procurement routes.

It is worth noting that many organisations will have a standard template for business cases, often in a simply structured and/or numerical format. These are organisation specific but will generally reflect the key elements identified above as a minimum.

2.3 Basic principles

The following principles are often used in business cases to justify investment as they provide quantifiable evidence of the benefits of a project. The basics of each are explained below:

Net Present Value (NPV)[2] - the present value of all cash flows minus the purchase price: it compares the present value of money today to the present value of the money at some point in the future. It allows the decision maker to see how much the money invested in a project will be worth in the future and so allows decisions to be made on where best to invest money (i.e. comparing one project to another to achieve the best return).

Discount Rate[3] - discount rate is a very important parameter for calculating net present value. The Social Time Preference Rate (STPR) is recommended by HM Treasury to be used as the standard real discount rate, as STPR is a rate used for discounting future benefits and costs, and is based on comparisons of utility across different points in time or different generations. Alternatively, discount rate can also be seen as risk-free rate of return. If a business has various funding sources to support different projects (for example, funding through equity market) a suitable discount rate in order to gain un-biased assessment on the present value of the costs should be applied.

Internal rate of return[4] (IRR) - The annualised effective compounded return rate, this is used to evaluate the desirability of projects or investments. This is defined mathematically as the discount rate which, when applied to a series of cash outflows followed by cash inflows, returns a net present value (NPV) of zero. It is a measure of the underlying return expected to be achieved by investing in the project.

Cost-benefit analysis (CBA) - a systematic approach to estimating the strengths and weaknesses of alternative projects or investments. It compares the cost of each option against the total expected benefits so that the preferred option can be identified.

2 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275125/webtag-tag-unit-a1-1-cost- benefit-analysis.pdf - page 8 for Net Present Value.

3 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275125/webtag-tag-unit-a1-1-cost- benefit-analysis.pdf - page 6 for Discount Rates

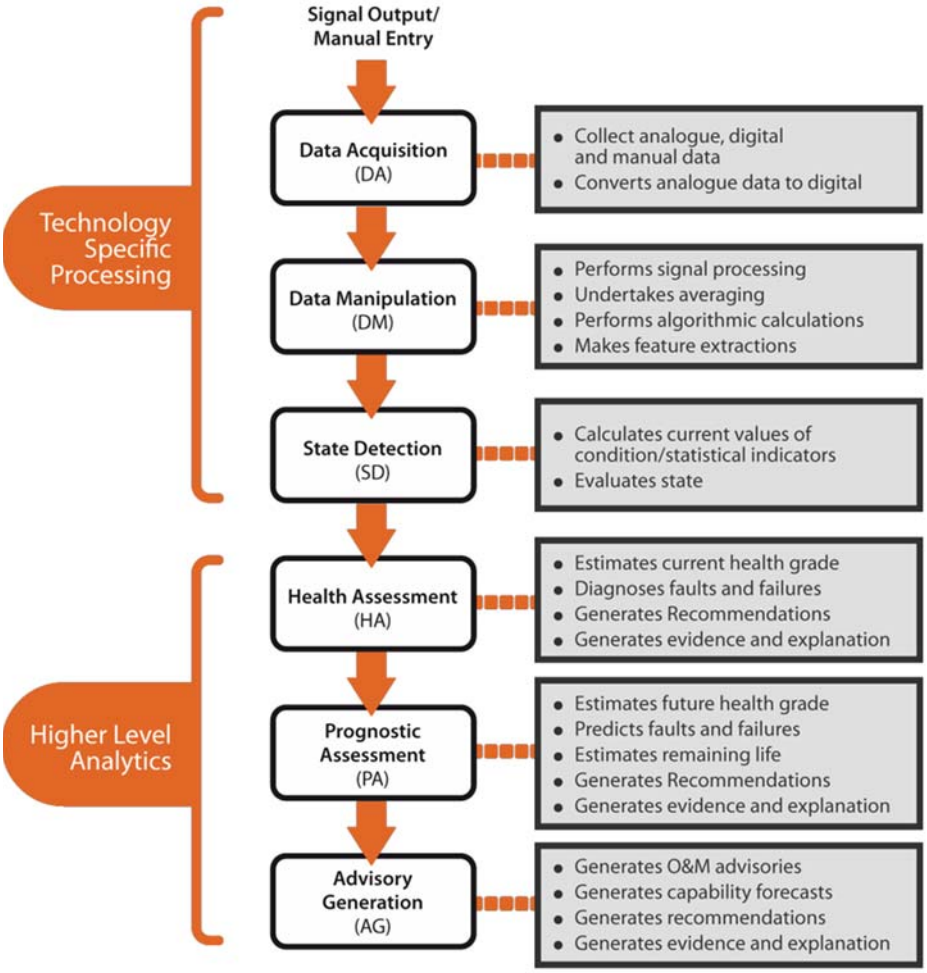
4 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225363/02_pfi_internalratesguidance1_2 10307.pdf

Whole life cost (WLC) - the total cost of ownership of an asset, including design and build or purchase, maintenance, operational, risk (such as safety, performance, and reputational), social and disposal costs.

2.4 RCM technologies

RCM technologies can deliver a variety of different functions to the infrastructure managers. This includes basic alarms and alerts when an asset is operating outside normal thresholds through to integrated works planning based on the condition states and forecast degradation rates. Levels of RCM processing are given in ISO 13374 'Condition monitoring and diagnostics of machines - Data processing, communication and presentation', illustrated in Figure 1. The levels of RCM processing can be taken into account in the business case, as discussed in Section 2.5.

Figure 1 - ISO 13374 RCM processing level framework



2.5 Options identification

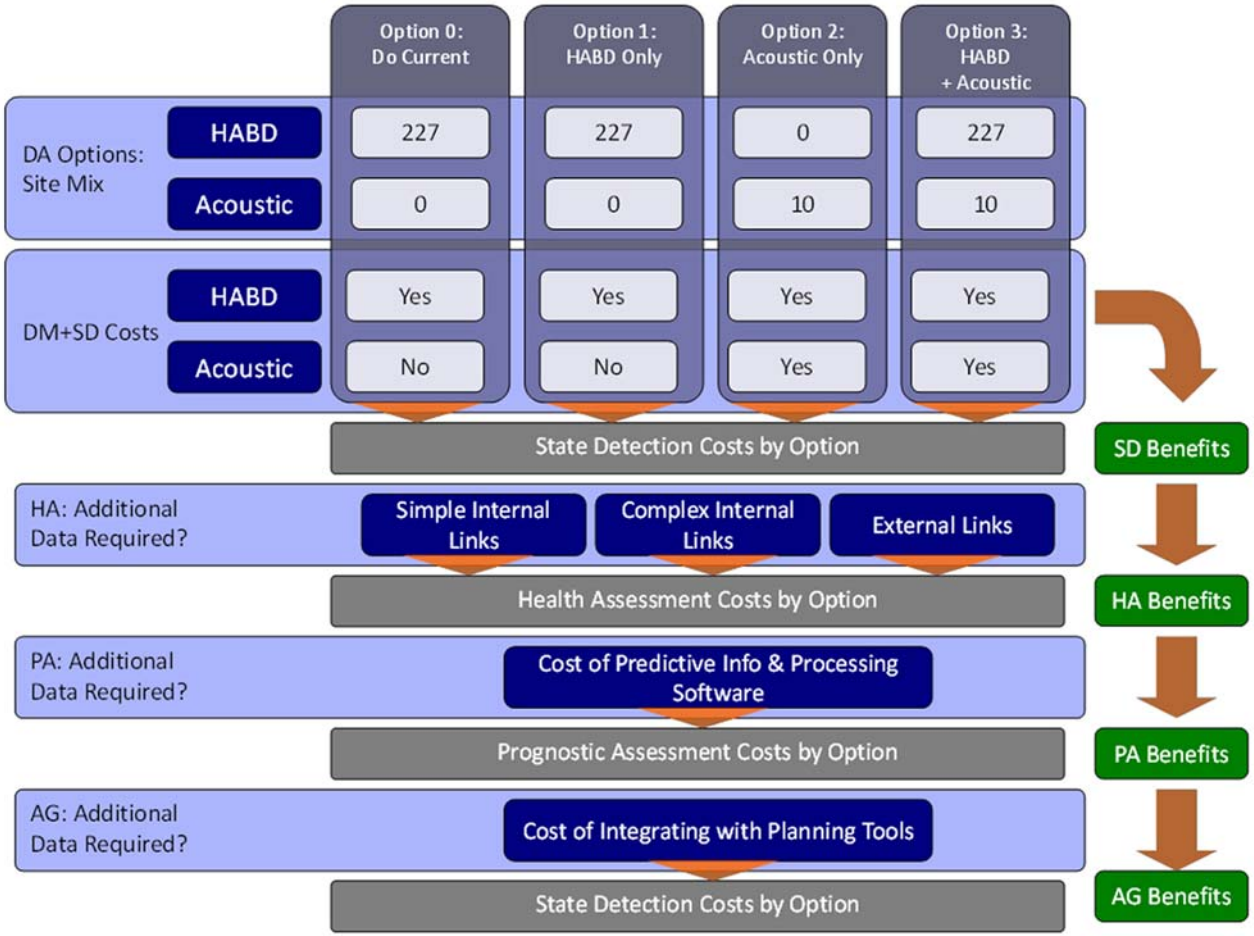
When creating a business case, research is essential to determine a manageable number of options that can be reviewed using modelling, covering both technology and the maturity level of the processing. For example, when monitoring axle journal bearings there is a choice between using hot axle bearing detectors (HABD) or acoustic monitoring technology, or both. There will be costs and benefits associated with the chosen level of maturity that will vary by option. There will then be additional benefits and costs in advancing further up the maturity scale (i.e. higher maturity RCM technology is more expensive but will deliver greater benefits). The value of each option can be reviewed over a set time frame using CBA.

To reach the 'health assessment' level will require linking and processing the 'state detection' information with additional data captured elsewhere. The cost of these links and processing will depend on the compatibility of the additional data with the existing data under the 'state detection' option. There will also be benefits from the additional data and processing. It is assumed that at this stage all data has been included to provide an adequate 'health assessment' for the asset, although the costs and benefits of doing so will depend on the option path taken.

The next stage brings in the cost of the additional software and processing to turn the 'health assessment' of the current condition into a plan for the asset; the 'prognostic assessment'. This is assumed to be the same for all assets, although the total costs and benefits to reach this point will vary by option.

The final stage brings in the cost of the additional software and processing to link the 'prognostic assessment' information to the asset owner's planning tools to deliver 'advisory generation'. Once again, this is assumed to be the same for all assets, although the total costs and benefits to reach this point will vary by option. This approach is illustrated in Figure 2 using HABD vs. acoustic monitoring as an example.

Figure 2 - Sample options evaluation[5]

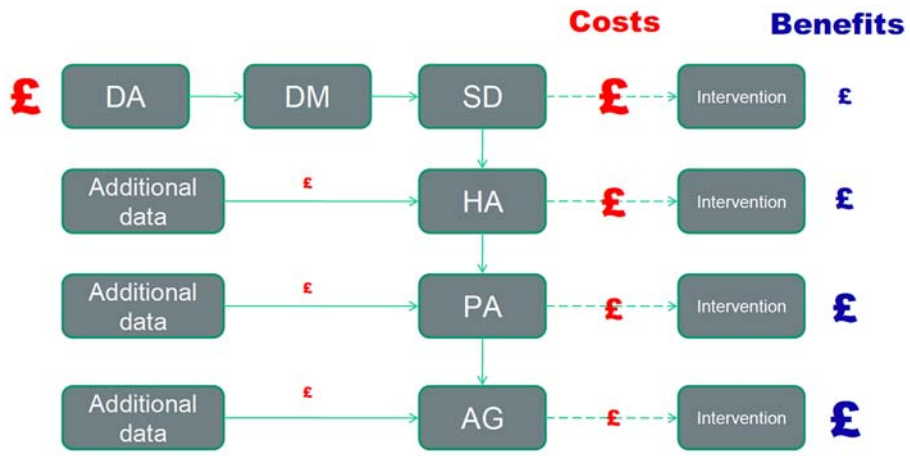


5 See Appendix B for the full list of abbreviations.

2.6 Business case analysis outputs theory

In the RCM Toolkit, or in any business case analysis, the 'Do Current' or 'Do Nothing' option is based on the existing industry position. For investment options to be analysed, the steps from the current to future state need to be valued in terms of costs and benefits. Benefits produced by RCM implementation (such as reduced asset failures leading to improved reliability and safety performance) are generated in the RCM Toolkit by assuming a percentage change in the underlying parameters driving the costs. These figures have previously been sourced from RSSB studies, studies commissioned by TOCs or from engineering judgement and experience (data sources are explained in more detail in the RSSB 'T857-06 RCM Toolkit User Guide'). The RCM Toolkit illustrates the costs and benefits of each RCM option as shown in Figure 3.

Figure 3 - Overall presentation of results for an option



As the RCM maturity level increases so the benefits will change, as will the financial implications (generally it is expected that as the maturity level of RCM gets higher, the incremental costs are decreasing while the incremental benefits are increasing.). In the RCM Toolkit both of these are defined by the inputs provided. These inputs are discussed further in Sections 2.7 and 3.3.

2.7 Calculating the total cost of RCM options

To fully understand the business case for RCM, it is important to understand the costs involved with any of the options proposed so that reasoned justification can be provided for choosing one option over another. The equations below explain how the main outputs are calculated within the tool. The same logic can be used to calculate these independently.

The total cost over a set period of time = Asset Risk Cost + Asset WLC including RCM cost. (The preferred option will usually be the option with the lowest total cost.)

The equations below will calculate each of these individual costs:

1 (Total) asset risk cost = total cost of safety risk (FWI)[6] + performance risk (cost of service affecting incidents) + other impacts (cost for major incidents).

This is the cost of the risk associated with the asset. This is made up of safety, performance and other risk.

2 **Asset WLC** = asset failure costs + maintenance activities cost (time based and usage based).

This is the total cost of the asset over its lifespan and includes cost when the asset fails (such as downtime and replacement cost) and maintenance costs.

3 **RCM cost** = cost to install RCM + failures (and service impact) cost + annualised CAPEX (installation & replacement) and OPEX (maintenance) + centralised labour costs.

This is the cost of RCM equipment, including installation (annualised), failure, maintenance and labour costs.

Net present value uses the defined discount rate in the Toolkit to discount the cash flow for each year, to reflect an unbiased view of the present value of the maintenance cost, risk, investment and benefit. This is calculated as a distinct value in the tool for each RCM maturity.

6 FWI is defined on P248 of http://www.rssb.co.uk/library/risk-analysis-and-safety-reporting/2014-07-aspr-2013-14-full- report.pdf

If there is a lack of data available it may be better to limit analysis to the scenarios that are sufficiently understood to ensure an analysis of a sufficient quality.

3 Using the RCM Toolkit to build the business case

3.1 Introduction

It is not the purpose of this document to explain in detail how the RCM Toolkit works or how to use it, the technical detail of RCM Toolkit is explained in the publicly available RSSB document 'T857-06 RCM Toolkit User Guide'[7]. However, it is important to understand the data required, as this is common to any thorough analysis of RCM options. Reference has been made where appropriate to the tool to facilitate understanding and data entry. This chapter also explains how the outputs can be used to build a business case.

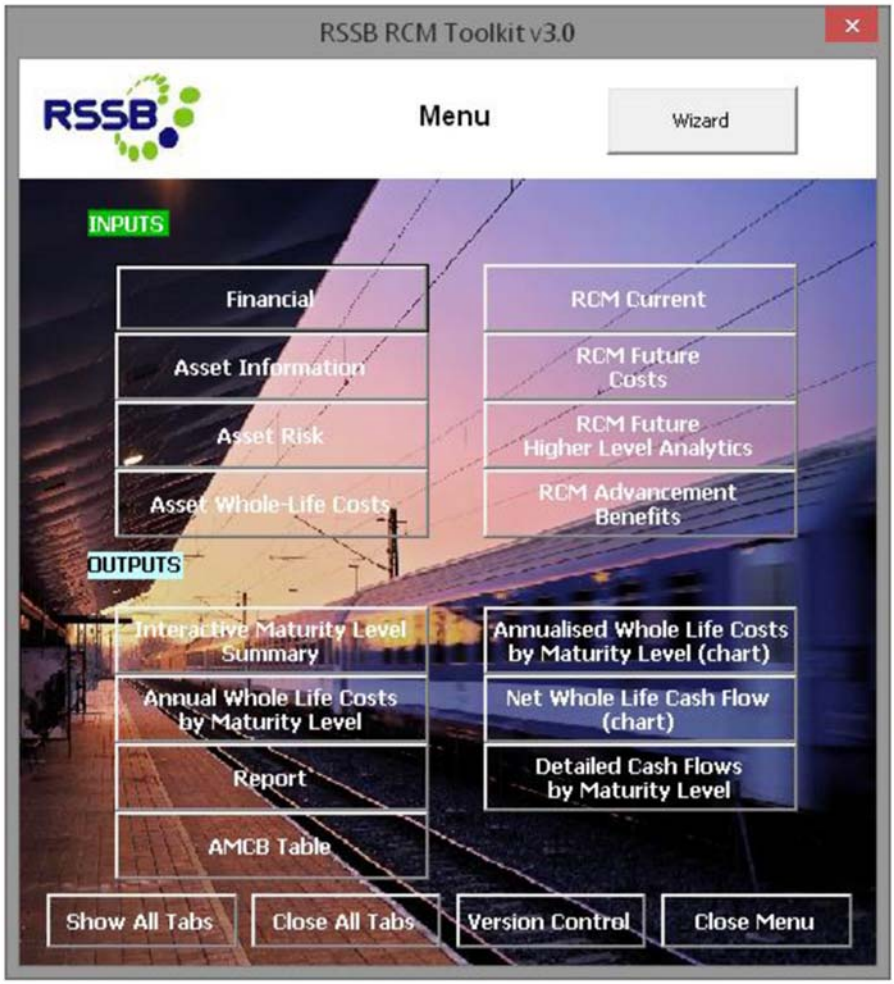
The aim of the RCM Toolkit is to enable users to compare different maturities of RCM technology and to understand the costs and benefits associated with each. This information can then form a key part of the options appraisal section in the business case, where the different options can be compared financially and the preferred option recommended.

3.2 Using the RCM Toolkit

The RCM Toolkit, as seen below, features a detailed 'Wizard' menu that leads users through a series of 20 steps to input the required information to the Toolkit. Not all stages are mandatory and each is clearly labelled and explained through the User Guide and through 'mouse-overs' (contextual dialogue boxes that appear as the mouse is hovered over the text) within the wizard.

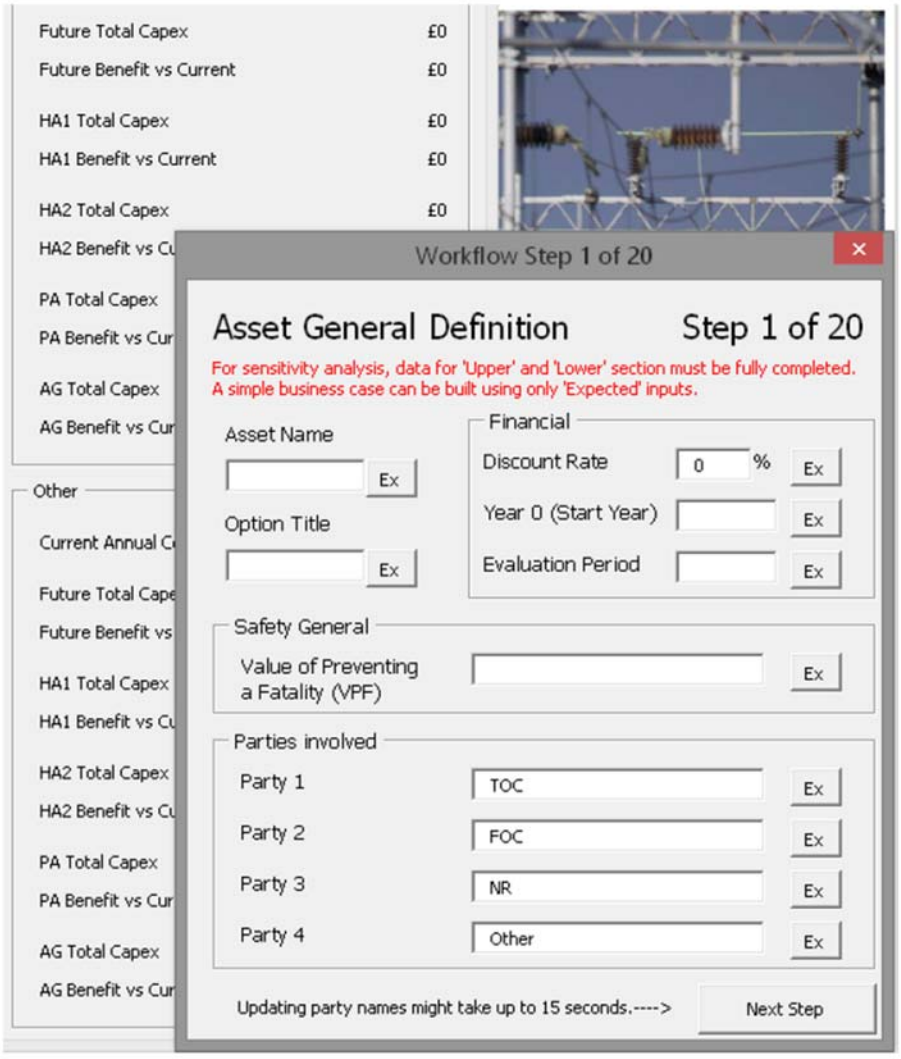
7 http://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=9922 (free website account required to view document)

Figure 4 - RSSB RCM Toolkit menu



Advanced users can skip the wizard (Figure 5) and input data straight into the worksheets by clicking 'Show All Tabs'. For a detailed explanation of the tool please refer to the RSSB 'RCM Toolkit User Guide'.

Figure 5 - RCM Toolkit wizard



3.3 Data inputs

The RCM Toolkit is reliant on good data input and the following data (Table 1) must be supplied to build a model in the RCM Toolkit. This information can also be used with any other tool to build a business case. Although a relatively large amount of information is required; for basic options comparison many of the input values can be estimates based on previous experience (particularly where historical or empirical data is unavailable) and these

should be sufficient to highlight the preferred option. Any estimates or assumptions can be revised as more data becomes available and each value can be revised in the RCM Toolkit at any time. As more accurate data is used the quality of the results will improve. If data is clearly explained and referenced then future revisions will be made simpler. In some cases, no data is required - see the RCM Toolkit for full details.

Explanations of the terms in Table 1 can be found in Appendix A.

Table 1 - Data requirements for building an RCM business case

Worksheet	RCMToolkit Wizard section	Subject	Data summary
Financial data	1-2	Business case	Discount rate
			Year 0
			Evaluation period
		Safety	Value of preventing a fatality
		Implementation timescales	For each RCM type
Asset information	3 - 6	Asset count calculation	Number of assets
		Asset utilisation calculation (optimal)	Average vehicle miles per year
			Average vehicle impact per year
Asset risk	7 - 10	Safety risk (FWI)	Asset specific
			Asset related
		Performance risk	Service affecting incidents
		Other impacts	Incidents and service costs

Table 1 - Data requirements for building an RCM business case

Worksheet	RCMToolkit Wizard section	Subject	Data summary
Asset WLC	11 - 14	Failures	Number of failures and cost
		Time-based activities	Maintenance services
		Usage-based activities	Maintenance services
RCM current	15 - 18	RCM installations	Name and number
		Failures	Faults per site and cost
			Service affecting failures
			Service impact breakdown
		Costs	Installation costs
			Service life
			CAPEX breakdown
			OPEX breakdown
		Central costs	Operating costs
RCM future	18	Data acquisition	Data acquisition site mix
RCM higher level analytics	19	Cost unit rates (expected, upper, lower)	CAPEX
			OPEX
		System configuration	RCM type implemented
		Total CAPEX, OPEX breakdown	Expenditure breakdown

Table 1 - Data requirements for building an RCM business case

Worksheet	RCMToolkit Wizard section	Subject	Data summary
RCM advancement - benefits	20	Reduced RCM Impacts	RCM equip failure reduction (%)
			Additional service impact reduction (%)
		Asset risk benefits	Asset failure reduction (%)
			Additional impact reduction (%)
		Asset WLC benefits	Reduction in time/ usage based maintenance activities (%)

Excluding information on the performance elements of the 'RCM Current' worksheet (which can be provided by the manufacturer or owner of this equipment), all of this information has to be provided by the Asset Owner. Indicative examples of each information requirement being entered into the RCM Toolkit and further, more detailed, guidance on how to complete each section is offered in Appendix A.

3.4 Data outputs

The main outputs from the RCM Toolkit are shown in Table 2.

For developing a business case, the main output of the RCM Toolkit to consider is the total annualised cost - this is provided for the current and future positions and for the implementation of each RCM technology. This cost includes the WLC minus the benefits realised (cost savings) and change in quantified risk. This number is a quick way to determine which of the options presented will be the most (or least) advantageous and therefore which option is preferred.

The annualised benefit vs. current shows the financial benefit of implementing the technology compared to the current position. If the benefit is positive, then the option delivers a cost saving relative to the current position.

The RCM Toolkit also incorporates a sheet that provides analysis of the monetised costs and benefits (AMCB) of factors that are not considered in the rest of the report and not calculated by the RCM Toolkit - such as local air

quality, reduction in accidents and environmental considerations. These factors may also be important to consider in any business case produced and have been incorporated into the RCM Toolkit for manual input or further consideration.

Table 2 - Data Outputs to Support Business Case Development*

Worksheet	Subject	Output summary
Report[a]	Annualised cost - current	Cost per party
	Annualised benefit vs current - future	Benefit per party
	Annualised benefit vs current by RCM maturity level	Benefit per party
	IRR - future	Cost per party
	IRR - by RCM maturity level	Cost per party
	Payback (yr) - future	Year per party
	Payback (yr) - by RCM maturity level	Year per party
Maturity level summary	Current total	Risk (annual)
		Cost (annual)
		RCM (annual)
	Future total	Risk (annual)
		Cost (annual)
		RCM (annual)
		NPV (Net cash flow)
		NPV / Investment (PV)
	RCM maturity level (HA1, HA2...) Total	Risk (annual)
		Cost (annual)
		RCM (annual)
		NPV (net cash flow)
		NPV/investment (PV)

a.Output cost values on the report worksheet are rounded to the nearest £0.1m.

3.5 Compiling the business case

Based on the RCM technologies and maturity levels to be compared and the associated data (see Section 3.3) that has been captured or estimated, the RCM Toolkit or the equations set out in Section 2.7 can be used to calculate the costs and benefits for each option and maturity level.

The business case should then be compiled following the outline in Section 2.2 of this report, ensuring that the costs calculated for each RCM technology are presented. As explained in Section 2.1, the benefits of completing the project must outweigh the costs, otherwise the project should not proceed any further.

RCM business case guidance: appendicesRCM Toolkit data inputs guide

A Financial data

Global financial parameters or company specific parameters can be added along with the estimated time for implementing system changes. These inputs are required by the detailed cash flow modelling sheets, and include:

- Discount Rate: The agreed rate for discounting cash flows to provide net present values at the 'Year 0' for the cost-benefit analysis.

In this version of the RCM Toolkit (version 3), the same discount rate applies to all costs and also to safety risk. This is an assumption made for this version of the RCM Toolkit, and because of the small value of the safety risk compared to the other business case drivers it does not have any significant impact on the comparison between options and maturity levels.

- Year 0: The initial year for the analysis (note that the year needs to be a number so it can be more easily added - financial years should be input as 2010 to represent 2010/11 for example).
- Evaluation Period: the number of years to include in the cost-benefit analysis.
- Value of Preventing a Fatality (VPF): this figure published by RSSB. The VPF is used to convert the safety risk into an equivalent financial value for fair comparison with other costs, benefits and risks and for input into the cost benefit analysis.
- Implementation Timescales: The number of years taken to implement each RCM maturity level.

A.1 Asset information

Asset count calculation: This is where the number of the assets being monitored is captured or calculated. For fleet assets (such as bogies, pantographs, and bearings) this is broken down by the number of vehicles (cars, optionally split locos and motorised vs. wagons and trailers) and the number of assets per vehicle. For infrastructure assets this is input as a direct count (although in practice this may reflect a continuous asset, such as kilometres of track or overhead line). There is an option to split between responsible parties - such as TOC, FOC, NR and 'other' owned assets.

Asset utilisation calculation (optional): This is optional additional data only required if asset lifecycle interventions are utilisation-based (such as for mileage-based wheel maintenance or tonnage-based impacts on track). The average utilisation (or duty) for the asset needs to be captured. Once again this can be split to allow different utilisations for different asset owners.

A.2 Asset risk

The following inputs need to be captured for a 'base year' - an average year where the level of risk reflects the current industry position with the current population of assets and current approach to RCM.

Safety risk: The equivalent Fatalities and Weighted Injuries (FWI) for the risks associated with the asset. Asset-specific risk should be that directly associated with the asset itself (such as the risk directly associated with axle journal bearings). **Asset-related** risk is used to capture other relevant risks that would be mitigated by improved monitoring of the asset but may not be directly caused by the asset itself (such as axle defects that can be spotted through monitoring the axle journal bearing). In practice, it does not matter exactly how the asset risks are captured here as long as the totals reflect the overall risk that can be mitigated through use of the RCM technology. Data from RSSB's Safety Management Incident System (SMIS) may be used to help calculate the safety risk and service risk.

Service risk: This needs to capture the service affecting incidents that are associated with the asset:

- **Asset-specific**: the number of service-affecting incidents where the asset is the root cause.
- **Other genuine**: the number of service-affecting incidents where the asset is not the root cause but where the asset can provide an indication for the failure.

The *delay minutes* associated with an average incident also need to be captured, along with the *cancellation percentage* (the percentage of incidents that are likely to incur a cancellation and significant lateness (CaSL) charge). The *delay cost per minute* and *cancellation charge* are then used to convert the expected number of incidents into a financial impact for fair comparison with other costs, risks and benefits and for input into the cost-benefit analysis. These figures can generally be found either through either Network Rail, TOCs, or FOCs.

Other impacts: Any other impacts can be modelled here, in terms of the more extreme incidents (such as a derailment caused by an axle bearing failure) or general wear and tear damage (on either infrastructure or rolling stock) that would be expected to improve with improved condition monitoring.

A.3 Asset whole life cost

The following inputs need to be captured for a 'base year' - an average year where the level of risk reflects the current industry position with the current population of assets and current approach to RCM.

Failures: The total number of (in-service) *asset faults* across all assets being monitored. While this figure needs to be input as a total, the *number of failures per asset per year* and *mean time between failures* (MTBF) are also calculated in this sheet to act as a sense check on the implied asset reliability as a result of using this figure. The typical cost of fixing an average fault (*reactive cost per fault*) also needs to be captured. Asset faults that are routinely picked up through out-of-service maintenance should be captured in the time- based and usage-based activities below.

There is an option to capture asset lifecycle management activities as either time-based activities or usage-based activities. Up to 3 activities of each type can be input separately, and any additional activities can be combined 'off-model' to be input as a yearly equivalent in the RCM Toolkit. This allows a relatively flexible means for capturing asset lifecycle management costs for different types of assets.

Time-based activities: For each activity the name (*Service x*), frequency (*Interval x*) and cost (*Cost x*) needs to be input.

Usage-based activities: For each activity the name (*Service y*), usage/ utilisation threshold (*Threshold y*) and cost (*Cost y*) needs to be input. The threshold is the point in the asset lifecycle (say after duty of 100,000 miles) that the intervention is required.

A.4 RCM current

The inputs required are based upon the ISO Maturity Levels for Condition Monitoring (see Section 2.4). They are split into 2 groups: the RCM equipment for the data acquisition, data processing, and state detection maturity levels; and the higher level analytics (through further hardware and software solutions) for health assessment, prognostic assessment, and advisory generation maturity levels.

A.4.1 Data acquisition to state detection

This picks up the costs associated with the lifecycle management of the RCM detection equipment, covering the activities associated with the data acquisition, data processing, and state detection maturity levels. This is generally the lineside or train-borne equipment (depending on whether the asset being monitored is infrastructure or train-based) and local processors that capture the data on the relevant parameters of an asset.

Space is provided to model a mix of up to 4 different RCM systems for data acquisition within an option. For each system the following data needs to be captured or estimated.

RCM installations: The name of the system and the number of sites at which equipment is installed. If a single location has several sites (multiple tracks) these should all be counted here. For equipment installed on a vehicle this should count the total of all of the on- board sites.

Failures: This is where to capture the number of failures for the RCM equipment (including false alarms), on a per RCM asset basis. These are the failures of the system and also any false alarms that bring additional disruption to the system through the presence of the RCM. Genuine activations are picked up in the 'Asset Risks' sheet. The *reactive cost per fault* (to the RCM equipment owner) should also be captured here. This is just the cost of fixing the physical fault. The additional costs in terms of Service Impact are calculated based on these overall faults by estimating a percentage of faults that have a service impact and the financial impact of the fault (via delay minutes and cancellation charges).

Data acquisition: This is where to capture the costs of the RCM equipment, such as *installation costs* (for steady state renewals calculations and estimating the cost of additional RCM sites to widen coverage of the monitored assets). This should include the cost of communications links at a site. The *expected life* of the equipment should also be estimated so this can be turned into an annualised cost. Note this is the full life of the asset, not the residual life. An annualised *maintenance cost* for each site should also be captured.

Data manipulation and state detection (DM/SD) operating costs: This is where the additional operating costs of running the central systems to further process and store the acquired RCM data should be captured. This is split into *labour*, *systems*, and *support* costs to cover various options for resourcing this.

A.4.2 Health assessment to advisory generation

This area covers the higher level analytics which is more about bringing data sources and systems together than installing additional RCM equipment. The costs involved are therefore slightly different to those for the earlier maturity levels.

Data and systems costs: This is where the additional CAPEX and OPEX costs of bringing together additional data sources for the higher level analytics are captured. Following consultation with relevant experts, AMCL considers it appropriate to have four different levels of complexity for this data linking in the RCM Toolkit. The costs of each of these types of links need to be captured here, along with any annual costs for storing and maintaining the additional data:

Data link: simple link between within a software system (such as linking 2 Oracle databases or 2 Gotcha-compatible RCM equipment types)

System link: link between 2 (relatively) compatible software systems within a company (such as linking 2 Windows-based applications)

Complex systems: link between obsolete or legacy system and more modern equivalents requiring custom linkages (for example: linking information from older equipment to an Oracle database)

External link: link between 2 parties within the industry (such as Network Rail system to TOC).

A.5 RCM future and higher level analytics

This is where different options will start to diverge in terms of the proposed mix of technologies and level of integration required. This is the forward-looking investment requirement aspect of the RCM Toolkit.

Option title: As this is the sheet where options start to vary, this is where the option is currently named. This should consist of an option number and brief description. A new workbook should be created for each Option as in the examples provided for each topic area.

RCM future: The inputs to this sheet are to propose a future 'steady state' *site mix* in terms of the number of sites of each RCM technology type. The costs associated with installing additional sites to get to this 'steady state' are then automatically calculated based on the data in the '*RCM Current*' sheet.

It is assumed that any redundant RCM equipment can be removed for negligible cost, no asset rationalisation or disposal costs are included in the

RCM Toolkit. This would need to form part of a detailed follow-up analysis once the high-level business case was accepted in principle.

The RCM higher level analytics information then consists of inputting the number of data links of each level of complexity required to move up the advanced maturity levels of health assessment (HA), prognostic assessment (PA), and advisory generation (AG).

Health Assessment is split into two levels:

- Basic health assessment (HA1): At this level the health of the specific asset is known (for example, by trending several readings on a bearing).
- Full health assessment (HA2): At this level the health of the associated assembly is known (by bringing in data on other elements of the bogie so overall assembly health is understood).

For some assets only HA1 will be required (so. zero cost for moving to HA2); for other assets the only way to realise the higher level benefits (such as changes to bogie maintenance and overhaul regimes) is to fully understand all elements of the assembly, so the move from HA1 to HA2 will be complex and require several data links.

A.6 RCM advancement - benefits

For each maturity level (DA/DM/SD, HA1, HA2, PA and AG) the expected benefits need to be input as a percentage improvement (decrease in the case of costs, increase in the case of things like maintenance intervals) on the current position.

All benefits are optional, and negative figures can be input to show increased risk or cost through losing RCM capability (or switching to less reliable technology).

Reduced RCM impacts: This picks up the benefits in improving the reliability of the RCM technology itself through better use of technology and data (for example: by trending HABDs so that false alarms through issues such as 'reflected sunlight' can be reduced). These benefits can be input as reductions in the number of failures of the RCM equipment, or as reductions in the number of failures that have a service affecting impact. The effects are cumulative, so reducing underlying failures AND the percentage of those which have service impact can be modelled as well as each individual case.

Asset risk benefits: This picks up the benefits in the RCM technology reducing the amount of risks associated with the assets being monitored. This can be input in terms of a reduction in the number of underlying failures, or as

a reduction in the number of these failures which are allowed to progress until they have a service, safety or other impact. This can be negative to reflect an increased risk. As for RCM impacts, these are cumulative so scenarios can be modelled where there are less failures, but more of these have an impact, for example.

Asset WLC benefits: This picks up the benefits of the RCM technology enabling improved asset management regimes that allow intervals between maintenance or overhaul to be extended due to better confidence in the condition of the assets. The option to differentiate between the asset owners (TOC/FOC/NR/Other) is allowed here to take into account that the scale of opportunities may differ depending on the owner.

B List of abbreviations

Abbreviation	Description
AG	Advisory generation
AMCL	Asset Management Consulting Limited
ATOC	Association of Train Operating Companies
AVI	Automatic vehicle identification
BAU	Business as usual
Capex	Capital expenditure
CaSL	Cancellations and significant lateness
DA	Data acquisition
DfT	Department for Transport
DM	Data manipulation
EMGTPA	Equivalent million gross tonnes per annum
FOC	Freight operating company
FMECA	Failure modes, effects, and criticality analysis
FWI	Fatalities and Weighted Injury Rate (or Index)
HA	Health assessment (HA1 is used to refer to 'Basic' HA and HA2 'Full' HA)
HABD	Hot axle bearing detector
ISO	International Standards Organisation
MTBF	Mean time between failures
OLE	Overhead line equipment
Opex	Operating expenditure
PA	Prognostic assessment
PV	Present value
RCM	Remote condition monitoring
RSSB	Rail Safety and Standards Board
SD	State detection

SWOT	Strengths, weaknesses, opportunities, and threats
TOC	Train operating company
TOPS	Total Operations System
TRUST	Train Running System TOPS
WLC	Whole life cost

RSSB R&D Programme
Block 2 Angel Square
1 Torrens Street
London
EC1V 1NY

enquirydesk@rssb.co.uk

http://www.rssb.co.uk/research-development-innovation/research-and-development