

# 10. Managing Ageing Rolling Stock



The purpose of this section is to increase awareness and knowledge of the factors to consider when identifying and managing ageing rolling stock. As well as how to mitigate the impacts to avoid significant reliability and performance reduction.

## 10 Managing Ageing Rolling Stock

All rolling stock has a predicted design life, where the fleets are expected to operate reliably and economically. However, components and sub-systems will invariably have to be overhauled, repaired or replaced along the way and the quality of this work will have a material impact on the lifespan.

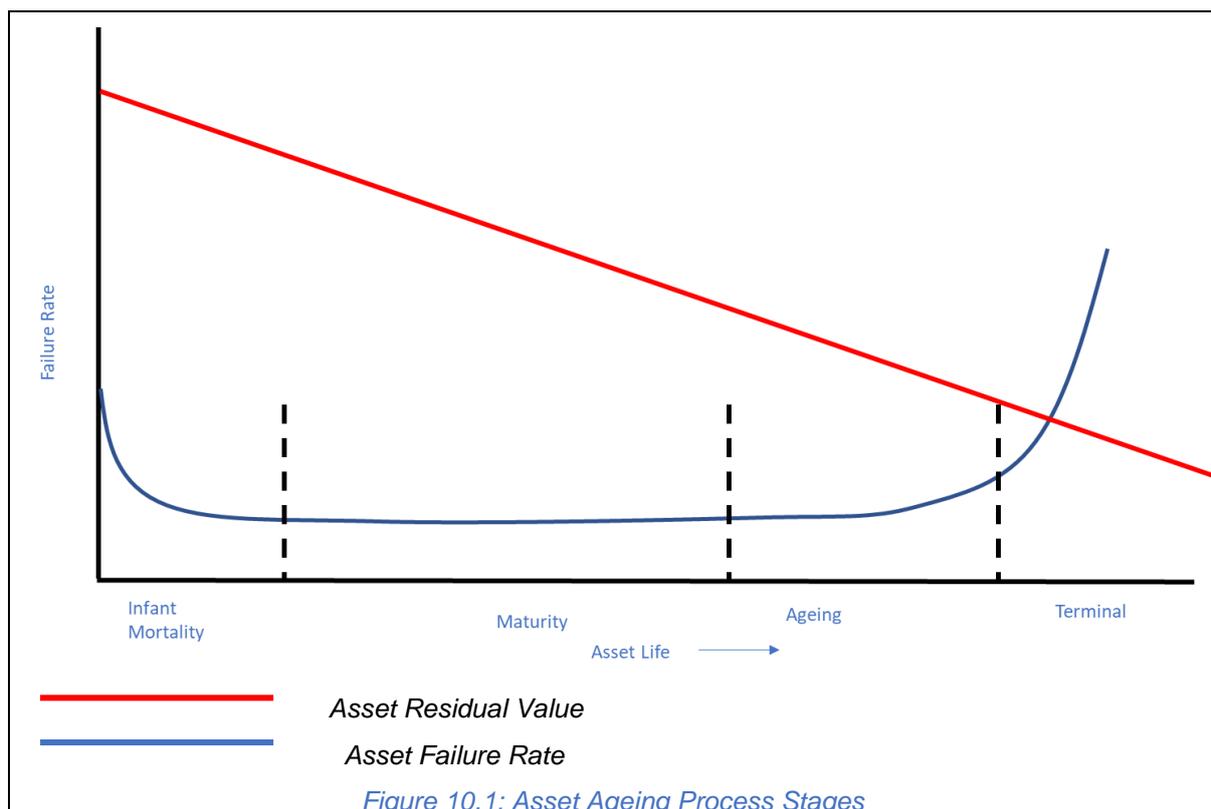
### 10.1 Rolling Stock Design Life

The 'bathtub curve' process model (*Figure 10.1*) is regularly used to show the phases of asset service life and can be divided into four stages:

*Infant Mortality* - During the rolling stock introduction stage, software, subsystems and components fail because of poor manufacture, insufficient design knowledge, testing or poor communication with sub-system suppliers on systems integration. More information on this phase can be found in [Section 14: New Train Introduction](#).

*Maturity* - Once the fleet introduction issues have been resolved, the asset enters a sustained period of performance and reliability growth. Fleet managers optimise maintenance by pushing out non-value-added activity and introducing new tasks where appropriate (*see Section 7: Depot*) and critical components are serviced and overhauled (*see Section 17: Overhaul Management*).

*Ageing* – Degradation, failure rates and costs are beginning to rise as rolling stock approaches midlife, stock levels of spares dwindle, and obsolescence, structural fatigue and corrosion set in. As the asset's residual value depreciates, developing business cases for investment is increasingly difficult. At this stage, the decision must be made for replacement or life extension. With effective cost control, modifications, enhancement and maintenance improvement, the usable life of rolling stock can be extended.

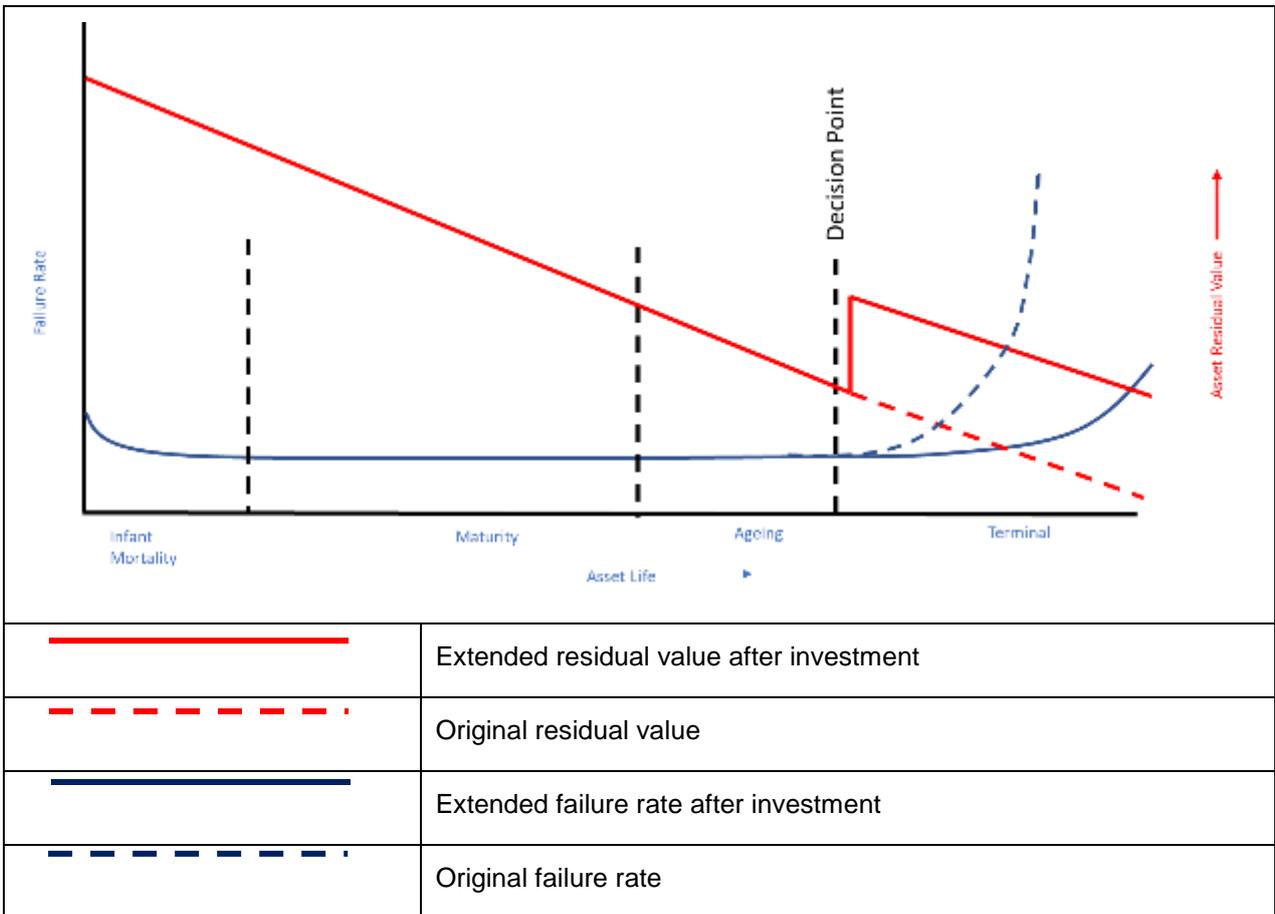


*Figure 10.1: Asset Ageing Process Stages*

Stages	Name	Characteristics
Stage 1	INFANT MORTALITY	<ul style="list-style-type: none"> <li>• Design and manufacturing faults</li> <li>• Early life operating faults (training, trials)</li> <li>• Interface issues</li> <li>• Software design, integration and testing</li> <li>• Slow performance growth</li> </ul>

Stage 2	MATURITY	<ul style="list-style-type: none"> <li>• Prolonged incremental performance growth</li> <li>• Planning for servicing and overhauls</li> <li>• Extending maintenance periodicity</li> <li>• Reducing maintenance costs</li> <li>• Condition monitoring and condition-based maintenance</li> </ul>
Stage 3	AGEING	<ul style="list-style-type: none"> <li>• Design limits approaching</li> <li>• Evidence of deterioration due to corrosion and fatigue</li> <li>• Refits and modifications required for operation and passenger comfort</li> <li>• Lack of spares</li> <li>• Lack of skilled labour</li> <li>• Maintenance costs increasing</li> <li>• Minimal residual value</li> <li>• Uncertainty around remaining life</li> <li>• Life extension investment decisions</li> </ul>
Stage 4	TERMINAL	<ul style="list-style-type: none"> <li>• End of life based on cost of repairs or replacement and economic value extending and descoping maintenance and overhaul intervals</li> <li>• Selective decommissioning of units</li> <li>• Decommissioning for spares to support remaining fleet</li> <li>• Repurposing facilities and staff for new trains</li> </ul>

Figure 10.2 shows that reinvesting at the right time will increase the rolling stock residual value; this in effect extends the maturity stage and time in operation.



	Boundary point (Decision Point)
--	---------------------------------

Figure 10.2: Extended Asset life after Investment

## 10.2 Management Process

The rest of this section focuses on *stage 3* of the asset life (*ageing*) but is not intended to be prescriptive. The ageing management process requires proactive maintenance, including asset condition assessment, monitoring and mitigation, acceptance criteria and performance standards, corrective actions, maintenance strategy, review and feedback.

Mitigating the ageing process has been categorised into four good practice stages:

- **Stage 3a - Understanding ageing** provides insight into the characteristics and problems defined as important.
- **Stage 3b - Decision points** outline both internal and external factors to consider before deciding on the best way to handle the impacts of ageing.
- **Stage 3c - Mitigation** offers two distinct maintenance approaches to reduce and manage the ageing rolling stock and its impacts.
- **Stage 3d - Feedback and review** on the objectives and feeding back lessons learned into maintenance plans.

The diagram below illustrates the process for better management outcomes.

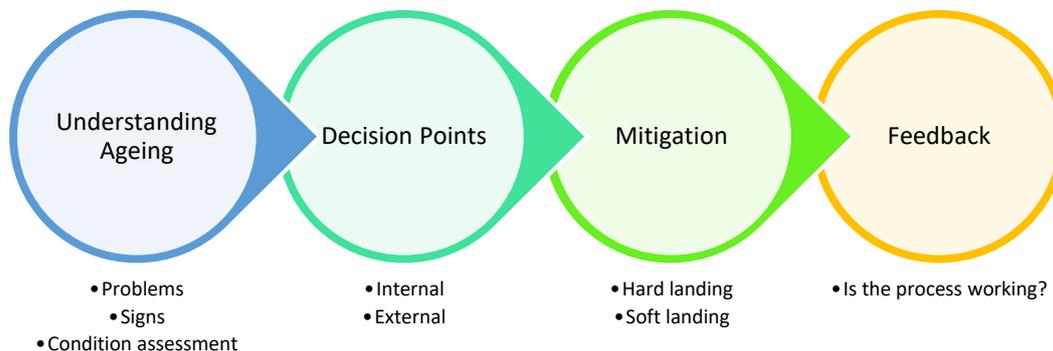


Figure 10.3: Mitigating the Ageing Process

### 10.2.1 Stage 3a: Understanding Ageing

The reliability and performance of the rolling stock can change during its life through age-related degradation, obsolescence and operational environment. Availability of the rolling stock, historical performance, reliability, maintenance and overhaul data are vital to identifying the level of ageing and monitoring performance trends. A defect identification process (see Figure 10.4) should be applied when inspecting vehicle structure, systems and components (see Figure 10.5) where failure would have a critical and direct negative impact on operational performance, safety and reliability.

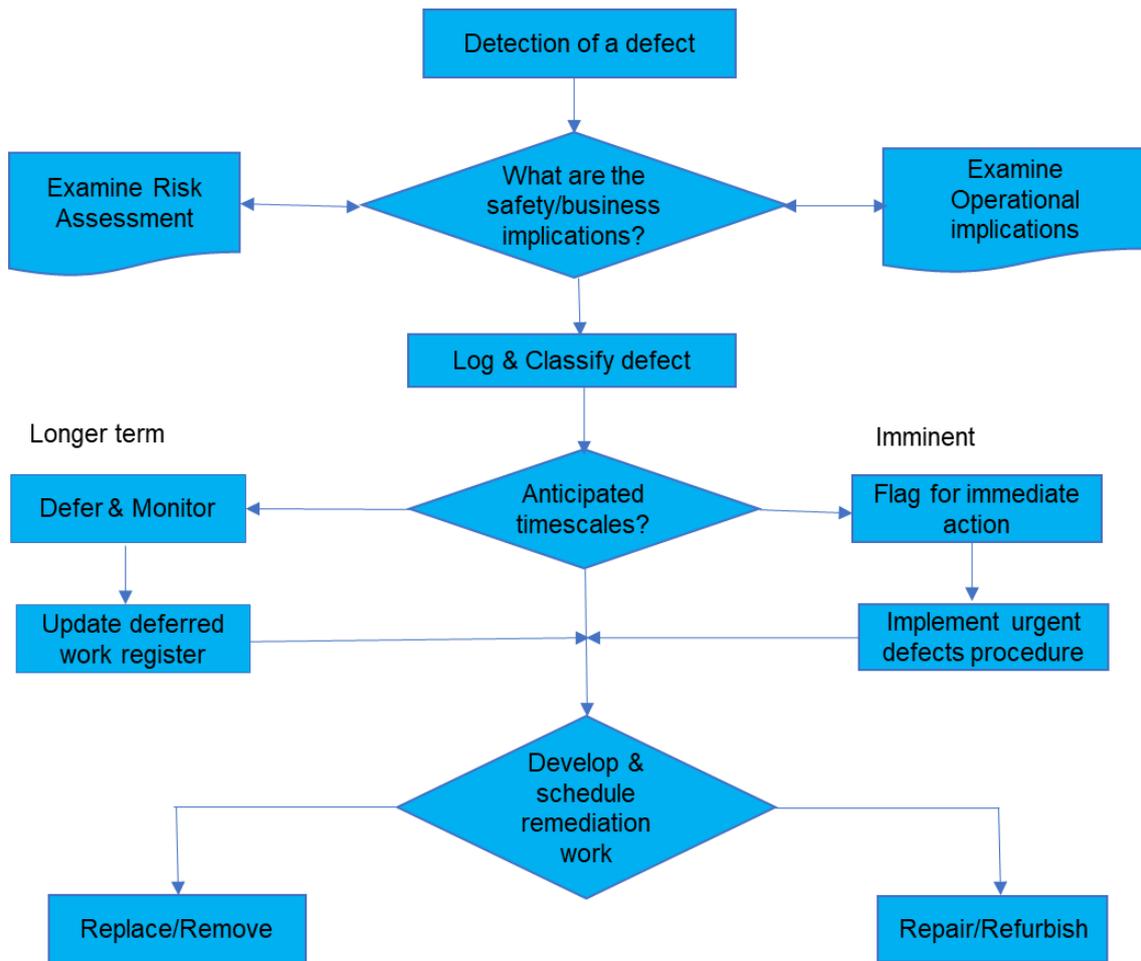


Figure 10.4: Flow diagram for reacting to defects from the perspective of managing ageing rolling stock

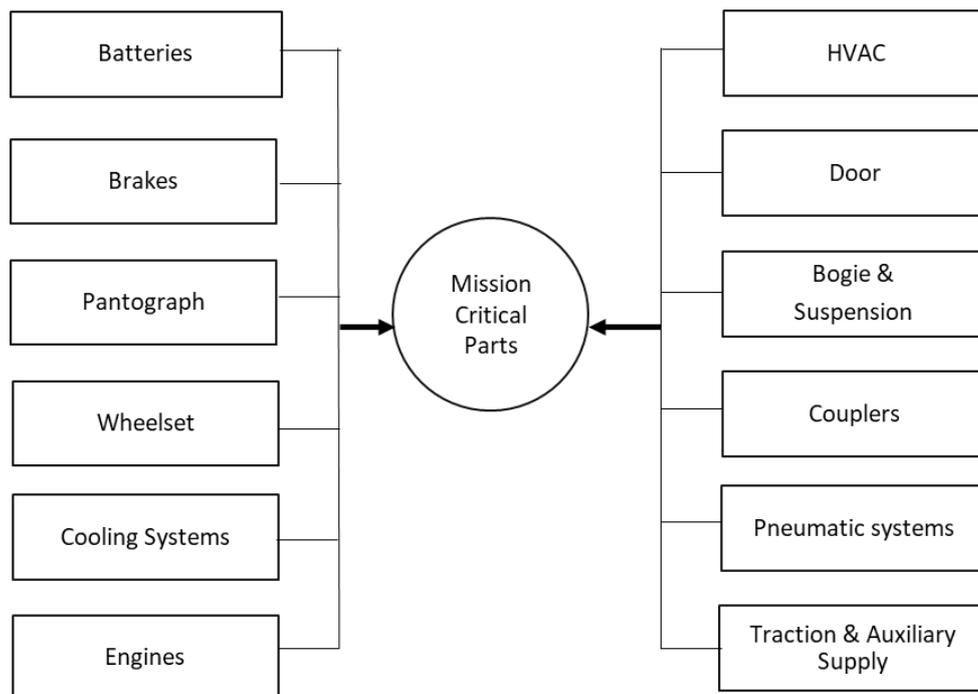


Figure 10.5: Mission Critical Parts

Some of the main degradation processes are corrosion, fatigue and obsolescence. A summary of the most common problems associated with ageing in any type of rolling stock is given in [Table 10.1](#). This is not an exhaustive list but seeks to provide an insight into factors which may be overlooked.

Characteristics	Impact
Obsolescence	Lack of spare parts, technical support or non-existence of the original equipment manufacturer is an indicator of an ageing fleet. There is a high probability that the components and systems from the original manufacturers will disappear over the course of the asset's lifetime. If the manufacturer no longer exists, then obtaining spares, original design drawings or replacement parts compatible with the existing asset can be difficult. This is an issue for electronic components and computer systems where the market moves quickly, and hardware and its manufacturers and suppliers change frequently.
Structural fatigue	Cracking of the metal bodies and bogies starts after long in-service hours, mileage, vibration and loose fasteners due to these components reaching the end of their design lives.
High corrosion (body thinning)	This is the physical degradation of material properties as a direct result of interaction with the climate or environment and the effect increases over time. It can also affect electrical connectors and cables.
New technology	Lack of compatibility with new or retrofit technology.
High parts failure and maintenance costs	As the rolling stock ages, so do its parts and components; constant random shock failure of different parts leads to high maintenance costs.
Reliability and performance decline	Besides the MAA MTIn, other internal reliability and performance KPIs will help to identify and monitor any decrease in the performance benchmark of the rolling stock.
Intensive resource consumption	Due to the sporadic and unexpected failure of components or systems, there is increased requirement for specialist resources such as fault-finders, system engineers, etc.
Relays & contactors	Contacts become eroded and pitted over time and can become welded together.
Wires, pipes & hoses	Degradation, blockage, corrosion; hoses wear due to vibration and movement.
HVAC	Loss of temperature control, reduced air quality and increased failure rate, especially in hot weather.
Wear and tear	Increase in deterioration rate, leakage.
Different lifecycle of components between overhauls	Each sub-system has a different deterioration rate; some may fail before the scheduled overhaul/maintenance.
Lack of support from relevant parties (design authority/OEM)	This can be as a result of a lack of expertise, economic viability or availability of the original rolling stock documentation or protection of Intellectual Property Right (IPR).
Lack of proper reliability management policy	As the rolling stock ages, there is the chance of a cultural shift among operators, maintainers, etc. leading to incorrect/lack of root cause analysis (tendency to tolerate failures and pass them off as the norm).
Loss of resources, skills/expert at depot & supply chain	For fear of redundancy or lack of essential skills, people tend to move to work with different rolling stock or stay with the trains and technology they know (newer or older). Due to fleet being withdrawn, there is a lack of enthusiasm to continue.

Characteristics	Impact
Lack of overhaul process/visibility of part numbers	Traditionally, overhaul was performed by highly skilled staff. Lack of proper documentation in relation to part numbers (cat. no., drawings, etc.) makes it difficult to comply with overhaul standards and replace failed components or find appropriate compatible replacements during overhaul.
Lack of spares pool	Shortage or unavailability of spares because of a single operator's fleet becoming cascaded to various operators exacerbating the problem.

*Table 10.1: Ageing Signs and Problems*

### 10.2.2 Stage 3b: Decision Points

These are high-level guiding factors to be considered before committing to or investing in the future of ageing rolling stock. For detailed risk analysis see [Section 3.2 Risk Evaluation](#).

#### 10.2.2.1 Re-franchising

This is one of the main driving factors. Any plans to accept or manage ageing rolling stock should be scrutinised for their economic viability towards the end of a franchise and the potential plans of future franchisees.

*Example: The Renatus vehicle enhancement and life extension was developed before the 2016-awarded Greater Anglia franchise; however, the new franchise announced a full fleet replacement. Such scenarios may be difficult to predict, but a risk-based approach can help.*

#### 10.2.2.2 New legislation

Is it economically viable for the rolling stock to be enhanced to ensure compliance with new legislation from government, regulatory bodies, etc. (e.g. *compliance with PRM TSI regulations*)?

#### 10.2.2.3 Economic viability

Asking the right and hard questions: how much life is left in the rolling stock, planned life extension, cascade options, enhancement, investment justification.

*Example: Choosing to extend the life of the Class 317s (which are limited to electrified routes) vs choosing to do so on a fleet such as the Class 170s, which can operate across most of the UK network.*

#### 10.2.2.4 Stakeholder expectations

The customer service-based expectations, comfort and journey experience (HVAC, Wi-Fi, new seats, new trains, etc.) are constantly rising due to high demand from the DfT (franchise obligations), Passenger Focus Group, etc.

*Example: Simply repainting the interior of a train is no longer sufficient when choosing to extend its life. The customer expects more, including air conditioning, plug sockets, etc. A successful example is the Class 168 or HST refurbishments, where many customers believed these were brand new trains, not just refurbished units.*

### 10.2.3 Stage 3c: Intervention and Mitigation

This section looks at options to mitigate the effect of ageing and ensure that chosen objectives are achieved. It also looks at how to evaluate when the replacement, cascade or scrap should take place in a cost-effective manner.

Mitigation management covers many activities such risk analysis, inspections, condition assessment, maintenance strategy, enhancement and, most importantly, whether the process is efficient and cost-effective. It is useful to have a simple system tracker for monitoring the condition of critical components and systems ([Table 10.2](#)).

Condition	Description
A -Good	Systems/components delivering all required functions to required levels of performance and reliability AND No signs of onset of ageing process
B -Acceptable	Asset delivering all required functions to required levels AND/OR Some evidence of the onset of one or more degradation mechanisms (excluding obsolescence) that currently pose no significant threat to the delivery of required functions
C -Poor	Levels of asset availability and/or reliability are below that required to consistently deliver required function(s) to the standard levels of performance AND / OR Evidence of (or reason to believe) significant progression of degradation mechanism(s) (including obsolescence) that are affecting or threatening key functions and need to be addressed
D -Unacceptable	Unacceptable levels of availability and/or reliability mean that the asset is currently unable to deliver the required function to the required levels of performance AND / OR Evidence of (or reason to believe) substantial progression of degradation mechanism(s) (including obsolescence) that are currently affecting key functions, or which pose an immediate threat to key functions.

*Table 10.2: Components/Systems Defect Classification*

#### 10.2.4 Maintenance Strategy

To develop a robust maintenance strategy framework (*Figure 10.6: Strategic Framework*) and SMART (*specific, measurable, achievable, realistic and timely*) objectives, the current asset condition should be assessed through its historic data. The involvement of key stakeholders, both internal and external, is critical.

There are two types of process available: **hard landing (end of life)** or **soft landing (continuous in-service)**. These two scenarios provide the basis for deciding whether the rolling stock continues in service, is re-purposed, repaired, enhanced or scrapped.

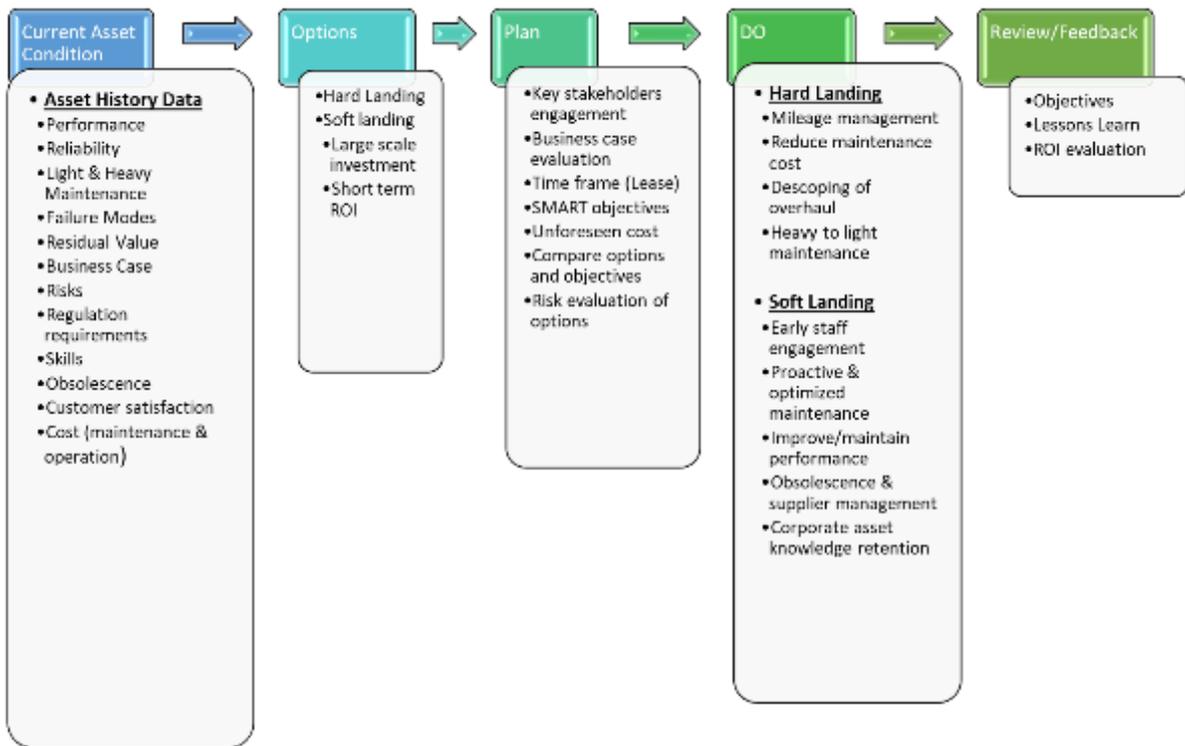


Figure 10.6: Maintenance Strategic Framework

### 10.2.5 **Hard landing**

This is when the TOCs and RoSCos are certain that the rolling stock is approaching the end of its life (scrap) without the option of life extension or cascade. To save maintenance resources and impact costs, alterations are needed to extract the remaining value.

#### 10.2.5.1 From heavy to light maintenance (L5 – L4)

All previous planned/scheduled heavy maintenance should be changed to light maintenance to save costs.

#### 10.2.5.2 Descoping of overhaul

Taking a risk-based approach instead of the normal/routine planned overhaul, skipping some tasks, repairing instead of replacing components, recycling spare parts from out-of-service units.

#### 10.2.5.3 Mileage management

Prioritising units with lower mileage in service (rotational). *See Section 11.4. Optimising for duty cycle*

*Example: Greater Anglia extended maintenance periodicities on their intercity fleet to enable overhauls to be pushed back to post-handback date. This prevented costly overhauls being undertaken close to withdrawal from service. The benefits included reduced costs for the RoSCo and improved availability for GA.*

### 10.2.6 **Soft landing**

This is when the rolling stock has the option of life extension or cascade and may remain in service. It is recommended to have a minimum of 2 years (franchise or asset contract) to plan for any significant enhancement. A review of scheduled maintenance is an essential element of the soft-landing process as it is the primary tool used to identify reliability variations and resource demand. The aim of the review should be to determine whether the maintenance policy is adequate and effective for the current condition of the rolling stock and is being correctly implemented in maintenance schedules to improve reliability.

#### 10.2.6.1 Proactive management (C6, C4, VMI - more inspection)

The use of a condition-based assessment approach for systems, sub-systems and at component level to determine the exact maintenance regime. Deciding which maintenance regime (mileage- or time-based) is best for the rolling stock due to its age and diagrams.

This should involve identifying key locations of structural fatigue (crack mapping) and proactively looking for corrosion at midlife and during routine/light maintenance.

#### 10.2.6.2 Body deterioration

Corrosion in steel-bodied vehicles needs addressing quickly. The use of fracture map reports and endoscope cameras is highly recommended to track and monitor the levels of damage, especially around hard-to-reach areas. Vehicles should be kept well sealed and watertight; rubber seals, floor condition, radiator water pipework and roof corrosion leading to hidden water leaks in the body should be monitored. Attention should be paid to door runners for wear, inter-car electrical jumpers and wiring for deteriorations, gearbox, bogies and traction motors for cracks and loose fasteners. Other innovative repair methods, such as additive welding and the use of composite materials, should be explored ([see Section 17.2.4: Overhaul specification](#)).

#### 10.2.6.3 Different lifecycle between components and overhaul

As the vehicle diagram changes and mileage per annum reduces, components may need more regular maintenance if it is mileage-based rather than time-based. Other critical time-based components are pantographs and air seals in large air-driven contactors.

*Running 50,000 miles per annum vs. 120,000 miles per annum makes a big difference to components such as rubber hoses, which perish over time, or air compressors which are overhauled on C4 exams that now take place every 10 years rather than every 4 as a result of mileage reduction.*

#### 10.2.6.4 Cascade (acceptor)

As an acceptor of the ageing rolling stock, operators should have strategic plans to maintain current performance and reliability as well as track failed components, etc. using historical data as a key performance benchmark. Door duty cycle change – cascade to a TOC with different diagram (longer/frequent) – will impact on reliability and performance. [Section 16.4: RoSCos: fleet transfer](#) contains more information on what to consider when accepting rolling stock from other operators.

#### 10.2.6.5 Staff engagement

Human error is always a concern with maintenance at all levels; managing ageing rolling stock requires a range of competencies such as familiarity with the fleet and design knowledge. Staff morale and maintenance quality might dip due to old rolling stock withdrawal (staff leaving) and new fleet introduction (with TSA maintenance agreement).

Early staff engagement and communication are important for the efficient and effective management of ageing rolling stock. A culture where it is easy to ask questions and point out problems will suffer fewer ageing-related equipment failures than one with a fixed hierarchy and less communication. Management encouragement for staff to learn beyond what is strictly necessary to fulfil their role will produce a more flexible and understanding organisation.

*Example: Upon the announcement of the new fleets, GA conducted a campaign of colleague engagement around the network looking to reassure those who felt uncertain about the future. Keeping colleagues informed and engaged with up-to-date developments and taking on board any feedback has helped to minimise the impact on morale, production quality and reliability.*

#### 10.2.6.6 Cultural changes

Tolerating failures and poor reliability of ageing rolling stock can become the acceptable culture, leading to reactive maintenance. A positive culture can be created through proper engagement, motivation and appreciation throughout the staff and supply chain to encourage failure root cause analysis.

*Example: With the introduction of new rolling stock and a TSA contract with manufacturers, some staff are not confident enough to TUPE across to the new, more technologically advanced rolling stock and prefer to work on the older fleets. This led to skills loss, cultural change and a loss of morale.*

#### 10.2.6.7 Knowledge transfer and retention

It is important to document lessons learned from successes (“Why did it go well?”) and failures (“What did not work properly and why?”) and make corrections and improvements. It is a good way of gaining trust and ensuring both knowledge retention and staff development.

There can be a wide gap in age and experience between established experienced staff and newly recruited colleagues. A lifetime’s knowledge can be easily lost upon retirement. It is therefore necessary to consider how to retain corporate memory and key equipment skills.

#### 10.2.6.8 Skills enhancement and empowerment

Any modifications, engineering or configuration changes should be reflected in the VMI and routinely checked for better configuration management. This is an end-to-end review and should identify what skills and competencies are needed to facilitate adequate training.

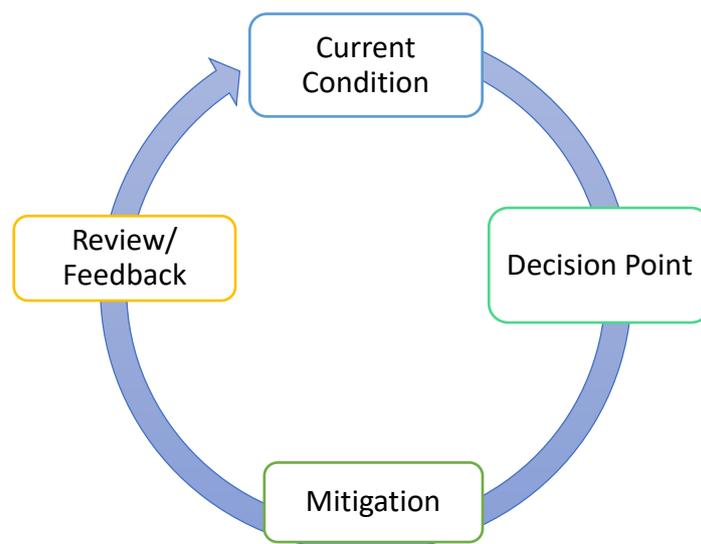
Staff should be incentivised, encouraged and given opportunities by management to solve problems and suggest/make improvements within competence limits and take ownership.

### 10.3 **Stage 3d: Feedback**

The management programme begins with understanding the ageing characteristics and impact, investment risk analysis, implementing mitigation actions and ends with feedback for evaluating its effectiveness (see [Figure 10.7](#)).

This helps to ensure that the process incorporates the latest information on rolling stock ageing signs, safety issues and corrective actions.

The end-to-end process should be evaluated through correct key performance indicators such as MTINs and asset current condition. The maintenance approach should be reassessed if mitigation is not preventing breakdowns, the effects of ageing or poor performance and reliability.



*Figure 10.7: Feedback Loop*