9. The Vehicles

Managing repeat defects, deferred work and configuration control; developing the maintenance regime and understanding availability.

9 The Vehicles

9.1 Data collection and analysis; repeat defects; trends

Reliability data is needed to understand what is happening where to concentrate effort and how effective that effort is. All TOCs feed into the common high-level reliability measures set out in *Section 2*. These are useful for looking at trends across the national fleet (and are reviewed at regular ReFocus meetings).

Within each TOC, more detail is needed for effective fleet management. Fleet engineers should actively design performance recording systems to:

- enable and encourage staff to record unambiguously details of operational events, the defective equipment condition which caused the event and the corrective actions they applied; and
- support subsequent statistical analysis and the identification of an appropriate long-term engineering response

Many operators call this type of record a Failure Mode Analysis (FMA). Best practice FMAs include:

- the operational event and impact, using TRUST and other data
- the observed failure characteristics related to actual equipment defective condition
- unambiguous identification of the failed component within the vehicle structure
- precise specification of the failure mode
- identification of the cause of failure
- the corrective action taken

Subsequent analysis is easier if:

- standard coding for all vehicle components underpins the recording system
- free format reports are minimised (difficult to analyse)

The above can be facilitated by an appropriate computerised maintenance management system.

Maximise/optimise data volume and integrity (capture all failures and as many potential failures as possible): sources of failure data should be drawn together:

- TRUST incidents (for failures which cause reportable in-service delays)
- Control logs (for failures which affect passenger comfort, e.g. air conditioning)
- Driver feedback (for failures which affect their working environment)
- OTMR, TMS, CCTV; modern and retro-fitted vehicles capture huge volumes of data. Off-train CCTV is also used for some incidents (e.g. to demonstrate that a door incident was caused by a passenger and there are no problems with the door itself, further investigation not required).
- Infrastructure data (particularly on shared systems, e.g. AWS, *see Section 11*

Example: Class 455 TAPAS retrofitted on Southern (with Eversholt). This system uses enhanced OTMRs to collect equipment performance data and wireless networks to communicate routinely with an analysis database. It is possible to detect incipient fault conditions and identify precisely the components involved (using Southern's vehicle/train model). When faults do occur, TAPAS can define the failure mode of the train.

Example: West Coast Traincare use digital pens at depots for arrival audits to enter defects (especially on passenger comfort) straight into SAP (their enterprise resource planning system).

Maximise depth of data (understand each failure): beyond the raw list of failures more data is required to understand each one fully. The underlying root cause must be identified and recorded in an FMA-type document. Periodic analysis and review using proper statistical techniques will then point to the long-term solution, e.g.:

- Inadequate fault-finding guide
- Defective material (supplier feedback, engagement)
- Error in vehicle maintenance instruction
- Insufficient understanding of personnel (training need)

Example: many TOCs use Fleet BUGLE to collate and analyse failure data.

Find the root cause – do not accept a "No Fault Found" without thorough investigation.

Example: TPE use TMS, OTMR, CCTV, door control unit histories, etc. to help identify what actually happened, with feedback to traincrew if necessary.

Example: Southeastern hold a root cause meeting to dig down and highlight lessons learnt in a reliability brief. This includes: top 5 Repeat Embarrassing Defect (RED) units, staff actions (e.g. recording any temporary repairs) and technical actions (e.g. develop new repair procedures, mend test equipment).

Optimise data sharing (get the right information to the right people at the right time to mitigate impact).

Example: war rooms are in use at many depots, with the longest established at East Ham. It is located where staff sign on and is also used for the daily morning meeting. If major problems arise on the fleet, there may be a 2-hour meeting there to keep all abreast of the situation. C2C seek a quickly implementable mitigation, minimising the effect on the service and allowing time for a longer-term solution to be devised.

Repeat defect management (dealing with the same apparent root cause).

- Provide the information to make clear it is not a repeat booking

Example: SWR's Aide Memoire supplements a heritage fleet data management system. Aide Memoire faults are coded by effect (not cause). This identifies repeat faults which would not otherwise show up due to incorrect initial diagnosis and is an effective supplement to root cause analysis work.

Example: Bombardier modern fleets are fitted with Mitrac which incorporates effective repeat defect flagging.

- Implement the management process for maintenance staff to be thorough, disciplined and consistent.

Example: Sole users of electronic components often track serial numbers, e.g. for static converters, so repeat defects at component level can be resolved (Bounds Green on Class 91 and Mark IV, Slade Green on Class 465). Soho openly display a 28-day rolling history of each unit and each technical system.

- Create staff development programmes to teach technicians about investigation and analysis. Do not expect key investigative staff and skills to materialise without nurturing and developing potential (*see Section 7*).

Examples: Tyseley's level checks have been widely adopted and depot engineer authority is required for a train to return to service after 3 failures of the same apparent root cause. Bombardier Central Rivers depot does not accept more than two No Fault Founds for the same defect: the train is not released until something relevant is found. The result is fed back into fault-finding guides.

Close the loop (analyse trends to ensure continued effective solutions and processes; identify promptly any need for further action or emerging problems).

Example: Dynamic Variance Charts developed by TPE, now being adopted (as Modus) in other First TOCs. Modus relies on measuring the actual performance against a standard or predicted level, so new or divergent trends can be rapidly identified. The system works well where there are multiple variables, e.g. on mid-life fleets where defects may have become embedded and their effects overlap, making it hard to understand the contribution of each.

Top 10 technical issues (target efforts rather than trying to fix too many defect root causes at once).

Example: Pareto analysis is generally applied to identify the 20% of work to fix 80% of problems. For technical issues, failure data tends to be grouped by system/function (e.g. door gear electrical, traction interlock system, door gear mechanical, AWS/TPWS equipment) and scored by severity (e.g. number of incidents, number of impact minutes). The systems with the highest scores are the top priority and progress should be reviewed regularly.

Example: EMT use Fleet BUGLE to feed a DRACAS (Defect Reporting Analysis and Corrective Action System) database.

The most frequent types of failure are given a DRACAS code and carefully monitored. Each has a champion who develops actions for improvement and progress is monitored at regular four-weekly meetings.

For example, DRACAS code X001 is ‘unsolicited brake applications’.

There are 9 recommendations arising from X001, including modifications, changes to VMI, compliance with existing instructions, staff training and track levels where units are coupled.

The benefits of each action are predicted and prioritised with progress against plan colour-coded.

Top 10 non-technical issues (reliability improvement is not just a matter of modifying trains).

Examples: At C2C, every TRUST incident is discussed with operations at a daily conference. A list of actions is produced to ensure follow up and close out. Sometimes C2C engineering may write a driver instruction to mitigate an issue. In addition to standard fleet metrics, at Groningen in the Netherlands, train faults are measured by driver diagram mile by depot. This highlights those who are unhappy/lack training/too rarely drive particular stock and enables remedial action to be taken.

Condition monitoring (how to prevent defects by gathering relevant data and feeding it into effective management processes).

Proactive data-sharing and trend-spotting can identify potential failures, which can be managed by sophisticated electronic call ahead or simple measurement systems and hence prevent actual failures.

Example (sophisticated): Remote Train Monitoring (RTM) is fitted to all AGA Class 90 and DVT vehicles. Any non-conformities against pre-set parameters show up in red and a history of previous defects can be called up.

A mimic of the cab layout shows the position or display of each switch, handle and gauge. A 'live' electrical schematic can be called up, showing which parts of circuits are currently energised.

This is used to advise a driver what steps to take to get a failed train on the move as soon as possible.

It also provides invaluable help with fault-finding, as the history of what parts of which circuits were energised when, is available for future reference.

Example (simple): FCC (now GTR) measure traction motor brush changes to identify rough commutators for grinding, reducing the risk of flashover. Brushes changed earlier than normal are flagged in red on XV (their maintenance management system). Diesel operators measure coolant top up at all locations to identify leaks for remedy at the next B exam.

Example: Southern have proven that OTMR data can be used to obviate the need for routine maintenance of brakes. They have also invested in bodyside door monitors on Class 455s to obviate routine maintenance and improve performance as the automatic system with SPC filtering is far more accurate than human beings.

9.2 Deferred work

Specific repair activities are sometimes deferred until the necessary vehicles, parts, personnel or other inputs are available. Vehicles with less deferred work tend to be more reliable.

Work can only be deferred where it is both safe (any risks acceptably mitigated) and commercially acceptable (running to timetable, toilet provision) to do so and TOCs have relevant decision criteria.

Once work has been deferred, best practice is:

- Weekly review of outstanding deferred work (London Midland)

- Lean review of process: GWR have created headroom in planned maintenance exams for defect clearance
- Each maintenance team shift briefed on which items to do
- Target zero deferred work off exam; each team monitored and benchmarked against this target (East Midland Trains)
- Feedback briefing to frontline staff (e.g. in communications room)
- Monitoring deferred work trends:
    - Number of items per vehicle (rate of decrease, although some TOCs had initial increases, as reporting improved)
    - Types of deferred work
    - Vehicle system affected
    - Reasons for deferred work (material unavailable, staff shortage, depot berth unavailable)
    - Number of operational events that can be attributed to deferred work

Deferred work trends are a measure of adequate production capacity and require action if the trend is not downwards.

Example: Soho have a deferred work database where the root cause of deferring each item, e.g. material shortages, is recorded to ensure that required materials/equipment are available before the unit is stopped for exam.

9.3 Configuration

The modification status of the vehicles and the parts fitted to them are required for a stable benchmark for reliability performance and meaningful fleet comparisons.

It is also crucial to know what materials to order, what maintenance regime to follow, etc., especially when fleets are split and combined across different franchises and ROSCOs. Clear records of configuration (vehicles and drawings) help with heavy maintenance, ensuring that the correct spares are ordered, and successful modifications are not undone. A standardised change management process should be used to control this (*see Section 3.5*).

9.4 Maintenance regime

UK rail vehicle maintenance has a long history of preventive examinations and corrective repairs, generally based on RCM principles, but there is always room for improvement. Triggers for change include:

- Feedback from failure data – extra/different maintenance may prevent failure
- Modifications which require less/different maintenance (part of configuration control)
- Condition monitoring which obviates routine failure-finding activity and identifies superfluous maintenance tasks
- Exploiting opportunities to make changes – testing changes in maintenance to check they are as beneficial as expected (e.g. more frequent filter renewals to prevent failures)
- Fundamental assessments of operational and business risks (*see Section 3.2- Risk evaluation*)

Example: Southern applied a proactive risk-based approach to its maintenance plan and identified that air system components had an inadequate overhaul regime and therefore posed a long-term risk. The result was a maintenance plan revision to enhance safety and performance standards. Southern's risk-based assessments also identified intrusive activities which introduced more risk than routine inspections but were inadequately addressed in the maintenance plan. This motivated improved instructions for intrusive activities and led to their inclusion in the competence assessment regime.

Recent developments in communication technology and data storage offer an unprecedented opportunity for radical change in rolling stock maintenance. It is now possible, even on mid-life vehicles, to monitor the operational performance of brake, power door, traction and safety systems. Eversholt's Class 455 is a good example. By careful design of data and analysis, maintenance activities have been modified based on data trends. This approach permits maintainers to eliminate many routine maintenance tasks, simultaneously reducing train downtimes, increasing rolling stock utilisation and releasing depot and resource capacity.

It is important to match the time for preventive examinations and corrective repairs to the downtimes agreed for service availability requirements. Exams may be *balanced* into even sized blocks (to fit in more easily with train downtimes and staff rostering) or *cumulatively* built up to more significant activities (where it is easier not to compromise the quality of work to fit too tight a downtime) (*see also Section 7.2*).

Examinations may be driven by time, mileage and/or duty cycles: the best driver often varies by train system, so the overall maintenance regime is often based on a mixture of all these. However, the more accurately the optimum periodicities for each individual activity are applied, the more complicated the regime is to manage, e.g. if excessive visits to depot are required. A compromise of grouping activities together is generally reached (for more details see *Section 12.4*).

Older rolling stock used to have a clear demarcation between light Level 4 maintenance and heavy Level 5 overhaul. Generally, Level 4 could be done in-situ between diagrams or at most when the train is stopped for a few days, whereas Level 5 required taking the vehicle out of service. Level 5 work often involved lifting the vehicle to change bogies, engines or perform a C4, or work on the body of the vehicle itself, including painting and C6

Modern vehicles rarely need Level 5, compared to some Mark 1 stock requiring annual (although mileage-based) bogie overhaul because of wear in moving metal parts. Modern vehicles run several years between bogie overhauls (which remain fundamentally mileage-based) because of advances in suspension materials and technology.

Integrating Level 4 and Level 5 saves vehicle downtime but requires tooling up formerly Level 4 depots, e.g. with lifting equipment and painting facilities. Integration encourages holistic maintenance (easier to trial changes, fewer parties to negotiate with, risks and benefits seen by same party).

Example: Work is in progress to extend Class 357 C4 from 450 000 miles to 1.5 million miles. The key to this is wheel condition. Wheel flats are very rare with modern WSP and planned reprofiling. The frequency of reprofiling is being increased so that the depth of cut can be reduced.

Example: At Onnen depot in the Netherlands, reprofiling is at 40 000 miles, a light cut to maximise wheel life. This is thought likely to be best practice for the UK too.

9.5 Understanding availability

A consistent and reliable level of availability must be established to prevent excess vehicles being unnecessarily leased or persistent failure to deliver to timetable.

Availability is affected by factors such as:

- Maintenance workload (including heavy maintenance and running repairs, i.e. all vehicle downtime)
- Modification workload (can be significant for the first few years of new trains, e.g. safety software upgrades)
- Diagramming (e.g. increasing the number of remote overnight stabling locations)
- Incidents (vehicles requiring significant repair can wait for months; a contingency plan must reflect the risk of these repairs on a particular route)
- Depot capacity and capability (*see Section 7*)

Example: GWR have a detailed 15-week plan showing all exams, heavy maintenance, etc., which is critical to ensuring a steady maintenance workload.

Example: At C2C, a 15-month painting programme required two units to be away for painting at any one time. Agreement was reached within the TOC to reduce the traffic requirement by two diagrams by de-strengthening and thus avoiding an impossible target.

Measuring availability. Availability has traditionally been measured at a particular time of day, typically just prior to morning and evening service peaks, e.g. '0600 stop position'. Availability requirement in the UK is often expressed as a percentage of the total fleet. Some TOCs include hot spares in the requirement and these may be shown as less critical. In other words, if the hot spare(s) is/are unavailable, traffic is not short but service delivery resilience is impaired *[Note that on the continent there are softer measures, e.g. number of trains supplied for traffic compared with plan, drawn from a much larger fleet. As ever, understanding exactly what is being measured is crucial for any meaningful comparison.]*

Example: Alstom (West Coast Traincare) has taken the '0600 stop position' a step further at VTWC with round-the-clock scheduled phone conferences (i.e. several availability counts during the 24 hours), which are used to plan depot slots and allocate staff to tasks on Pendolinos.

It is hard to make meaningful comparisons (especially at the high-level fleet % measures) but detailed ReFocus data has been used to justify increasing fleet size in other TOCs. The extra vehicle leasing costs to make availability deliverable were justified by reliability performance improvement. It is of course possible to make available a sub-standard vehicle, but a vehicle truly fit for purpose can only be provided through a successfully completed sequence of specified management processes. Defining these processes and understanding their relationships and dependencies is therefore necessary for sustained success. This work will almost inevitably stimulate change projects (*see Section 3.1*). As a minimum, improved understanding will help management reduce the number of times sub-standard vehicles are offered for service.

Critically, **the reasons for each unavailable vehicle must be identified, recorded and trended within each fleet/TOC** to identify improvement opportunities and measure their success or otherwise.

Typical reasons for unavailability are:

- Maintenance planning (peaks and troughs or combinations that exceed organisational capacity), e.g. B exam, C4, C6, other maintenance/repairs arising, e.g. modifications, condition-based work
- Out-of-course repairs, e.g. vandalism damage, collision damage
- Waiting, e.g. material, specialist staff, shed space, test run
- Failure investigations, e.g. repeat failures

Example: Cross Country used Wheelchex to plan tyre turning and prevent availability problems. A rolling 28-day chart (updated daily) in the planning office at Central Rivers shows any Wheelchex reports greater than 150 Nm. Impact loading increases over time, visual inspection is scheduled and then tyre turning prioritised. This modifies the baseline 250 000-mile conditioning re-profiling programme. In addition to improving availability, the use of Wheelchex data has enabled better use of the Central Rivers wheel lathe and reduced buy-in slots at other lathes.

Example: Mileage is carefully managed at C2C by using shorter or longer mileage diagrams. The tolerance on exams is set at – zero, + 500 miles. All exams are planned within the +500 miles range and done slightly late. This ensures the fleet is not over-maintained, giving best availability of units and saving costs.

Example: TPE use a 43-day plan for each Cl185 unit. The units almost due for exam are allocated to higher or lower mileage diagrams and therefore close to the target mileage, reducing waste from carrying out exams early.

Balance availability and reliability. Once the long-term level of availability is set, it is important to balance availability to ensure reliability is not compromised. Best practice is to develop a culture where repairs are done to promote reliability, rather than deferred to chase short-term availability at any price.

Example: some TOCs have agreed contingency plans such as running 3 cars vs 6 on certain trains if necessary, e.g. carrying out thorough level checks on repeat failures (see 9.1 Repeat Defect Management).