Back to basics: Points maintenance and remote condition monitoring

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In this article, which continues the Back-to-basics series on points (see February and March 2022 editions of IRSE News), we will be considering three general and related subject areas: scheduled maintenance; fault-finding; and how Remote Condition Monitoring (RCM) can assist with both of these. Initially we will consider faulting and maintenance in the more traditional sense BC (Before Condition monitoring!), and then move on to AD (Assisted Digitally!).

Timely and effective maintenance of the point actuating mechanism and the Switch and Crossing (S&C) is essential for the safe operation of the railway. As far as possible, signalling technology developments have tended to reduce or eliminate moving and mechanically vulnerable parts such as relays, filament lamps, searchlight signals and physical panel controls. However, so long as wheels run on rails there will always be the need to switch trains between tracks, and therefore points will be required.

Why maintenance matters

It is not hard to envisage that a mechanism pushing with a force measured in thousands of Newtons, to millimetre accuracy, that is run over by hundreds of tons of train moving at speed will need to be maintained on a regular basis to keep it in reliable working order! Maintenance of points, as with other signalling assets, must be performed at intervals that are frequent enough to ensure any signs of deterioration are captured and rectified on a timely basis, especially where safety is concerned.

The maintenance can be considered in two parts: the track, covering the rails, chairs, crossing etc.; and the signalling, covering the point actuating, lock and detection mechanism. Inevitably these two functions overlap, and representatives from both departments may attend the same maintenance event to perform their specific tasks, whilst also advising and assisting the other department in theirs. Other personnel might also be involved, for example to maintain point heating where required; in the UK this is usually undertaken by Electrification & Plant (E&P) personnel, and is outside the scope of this article.

Ultimately the purpose of all maintenance is to ensure the asset is presentable, operating safely, within acceptable (preferably optimal) parameters, and is able to do so for as long as possible. Maintenance activities can therefore be divided along these lines: safety; performance; and life (prolonging) - with a number of them falling into more than one category. Maintenance can also be divided into preventive maintenance and corrective maintenance.

Scheduled (preventive) maintenance

For reasons stated previously, scheduled maintenance is by its very nature preventive maintenance; it is aimed at ensuring that the equipment remains in good working order. The nature of the maintenance can range from a simple visual examination to cleaning, re-greasing, measuring and gauging. Gauging (testing for mechanical correctness using a tool of known dimensions) and measurement (using a scaled instrument to determine a quantitative value) might reveal that the equipment is out of tolerance and requires adjustment or renewal. Visual examination might also reveal defects that need to be corrected.

Corrective maintenance

If during scheduled maintenance some property of the points is found to be outside the acceptable parameters it will be necessary to carry out corrective maintenance. This could be as simple as a small adjustment to the drive or detection, or as complex as switch or machine renewal. Clearly the nature and severity of the problem identified will determine its priority in planned works. If the problem is safety related and cannot be rectified immediately it might be necessary to restrict the use or position of the points, and/or the speed of trains over them.

Scheduled maintenance intervals

Scheduled maintenance is generally divided into two types. Firstly, a frequent service activity covering light maintenance and essential safety checks might be carried out once every three months, or as recommended by the manufacturer. Such

Points and crossings are an essential part of the railway infrastructure, and their effective maintenance is critically important. Their location often poses challenges in carrying out this work safely and without disrupting service.

servicing might be performed more frequently for 'key points' whose operation is in high demand and therefore essential for many train movements, such as at a junction where two busy routes converge. Failure of these key points would incur high train delay penalties and/or damage the reputation of the train operator.

In addition to this, a more detailed maintenance activity is undertaken less frequently, typically annually. This includes further tests and checks on components that are not expected to deteriorate quickly, for which an annual check is sufficient.

Maintenance standards

The maintenance standards adopted by a particular infrastructure owner/maintainer might be the manufacturer's recommendations and instructions themselves, as is the case in some countries. Alternatively, the manufacturer's recommendations may be used as the basis of standards produced and issued by the relevant authority (e.g., Network Rail, in the case of the main line in Great Britain).

Each approach has its merits. Following the manufacturer's instructions directly, once approved by the relevant authority, is a potentially easier and more direct approach, whereas standards produced by the infrastructure owner will have the advantage of being consistent across all types of assets, and take into account the individual needs of the infrastructure owner that the manufacturer might not include.

It is beyond the scope of this article to consider all the myriad forms of point operating mechanism and associated specific maintenance activities. But most points share common categories of maintenance activity, as shown in the following example. This brings together the considerations and factors discussed so far and puts them into context. Although some standard British mainline railway documentation has been referenced, the principles are likely to apply to the majority of cases on other railways.

Permanent Way maintenance

Before attempting to check the correct operation of the points operating mechanism it is necessary to ensure that the trackwork S&C is in good working order; there is no sense and indeed some danger in adjusting the point operating mechanism to compensate for an S&C problem.

First and foremost, it is essential that the track gauge at the points is correctly maintained throughout the whole length of the points at all times. If the rails are out of gauge anywhere in the S&C, temporary measures might be implemented, such as using packing pieces, to restore the correct dimension. However, a permanent fix, such as overhaul and renewal of components, should be arranged as soon as possible.

Secondly, it is important that the integrity of the rail furniture such as chairs and stretcher bars (where provided) is maintained. The traditional design of stretcher bars has come under considerable scrutiny in recent years and new products have been introduced in many cases. Mechanical stress in the traditional stretcher bar can be high and result in metal fatigue, most commonly seen as broken bars or brackets ('shoes'). Chair bolts, rail fastenings and stretcher bars must all be examined and tightened, adjusted or replaced as necessary. Wooden sleepers in particular should be checked for signs of deterioration. Switch rails should move smoothly in the slide chairs without excess friction (more about this later).

Thirdly, the profile of the rails should be checked. Switch and stock rails are shaped (profiled) to fit together tightly when closed so, as to present a relatively smooth transition for passing trains. Over time both the stock rails and switch rails can wear. Stock rails may show 'lipping' where the rail head has been rolled out and this may even risk fouling the switch rail. Switch rails, being very narrow at the tips, are prone to chips and cracks if not aligned correctly and could be struck by passing wheels. Repair work such as grinding or welding is likely to be needed, and ultimately renewal might be required.

Fourthly, the lateral movement of the switch rails on the slide chairs needs to be checked. One of the most common and frustrating issues with switch rails is combating the friction that is inevitably associated with sliding components. Initially the chairs will be greased but as the points are moved the grease will be progressively worn away, and can build up in places where it might interfere with the operation of the points. Removal of old, tarry grease deposits and the application of new lubricant is necessarily a frequent maintenance activity, otherwise the slide chairs will become 'dry' and the excess friction will cause increasing stress on the point mechanism, until eventually it is unable to complete the movement. Innovations to address this have included using materials with naturally lower friction, such as nylon, or providing rollers in the slide chair that support the switch as it moves into position. In both of these cases grease must not be applied as it can interfere with the correct operation of the components.

Finally, and perhaps harder to ascertain, is the stability of the ballast. As anyone who has watched train wheels pass over points or indeed plain line will confirm, seemingly solid and immovable rails will bend visibly under a passing train to some extent, depending on its speed and weight. Over time this can lead to 'voids' in the ballast leaving the points partially unsupported and possibly twisted or warped. Visual inspection might indicate that voids are present, or train-borne or trackside instrumentation may provide evidence.

Some point mechanisms, notably ones that clamp the switch and stock rail together, are notoriously sensitive to this kind of rail deformation and can fail at short notice. Adjustments made to compensate for the rail deformation might overcome problems such as loss of detection, but then be defeated when the track moves again.

There are various ways of preventing or reducing the risks associated with voids and rail deformation. Solid track (slab track), which has a concrete base, does not suffer from this problem of course, but is more expensive to produce. Some companies offer chemical or mechanical products to help stabilise the ballast formation. The problem of point failure as a result of rail deformation can also mitigated by the use of 'in bearer' operating mechanisms, which are contained within a steel sleeper.

Signalling maintenance

The activities listed here are typical, but might not all be relevant for a given installation or environment, and some operating mechanisms might require additional signalling maintenance activities.

Signalling maintenance personnel need to pay attention to the S&C, not just the points operating mechanism. Some maintenance measurements are made by both track and signalling personnel. These include free wheel clearance (FWC), free wheel passage (FWP) and residual switch opening (RSO). All of these measurements are aimed at ensuring that on the open switch rail the train wheels have sufficient space to run without causing 'flange back contact', whereby the back edge of a passing wheel flange is rubbing against the back edge of the open switch rail. Such an event risks the wheel riding up on the switch and causing a derailment, as happened at Grayrigg, Cumbria, UK, in 2007.

FWC and FWP are checked by running a gauge towards the heel end of the open switch rail. Additionally, it is necessary to measure the distance between the open switch and the stock rail at the toe; a typical value for this is 108mm but it can vary by switch type.

Checking the RSO involves measuring the gap between the closed switch rail and the stock rail where the rail head profile is shaped to ensure the two fit together well. This measurement is made at intervals from the toe towards the heel end of the switch rail. Figure 1 shows the typical measurements made.

Signalling maintainers will check for the tightness, correctness and security of points fittings and stretcher bars (where provided), drive mechanisms, cranks, rods, detectors etc. to ensure that nothing is loose, cracked or out of adjustment. Seasonal maintenance may include additional measures, e.g. to minimise frozen points in winter by applying frost-resistant grease.

The environment in which the points are operating must be checked for cleanliness and freedom from potential obstructions. This means removing debris such as litter and vegetation that could find its way into the gap between an

Figure 1 – Simplified diagram of typical measurements made during maintenance. *Based on diagram in Network Rail standard NR/SMS/Part C/PF01.*

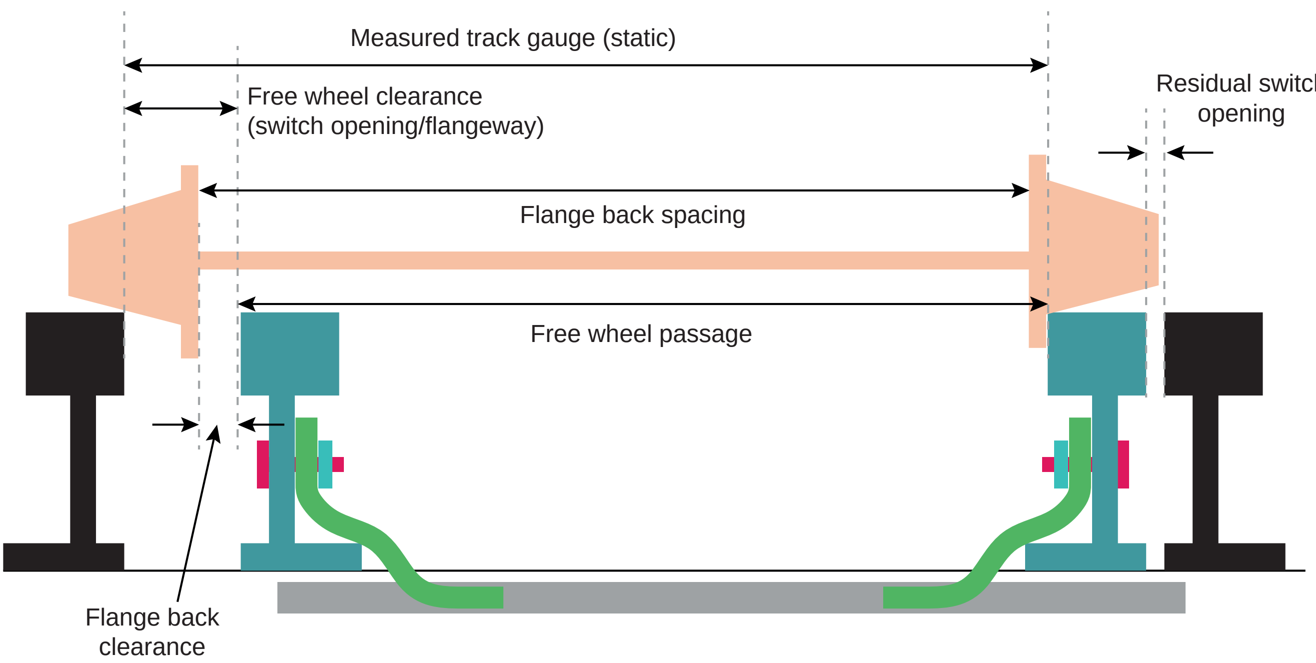
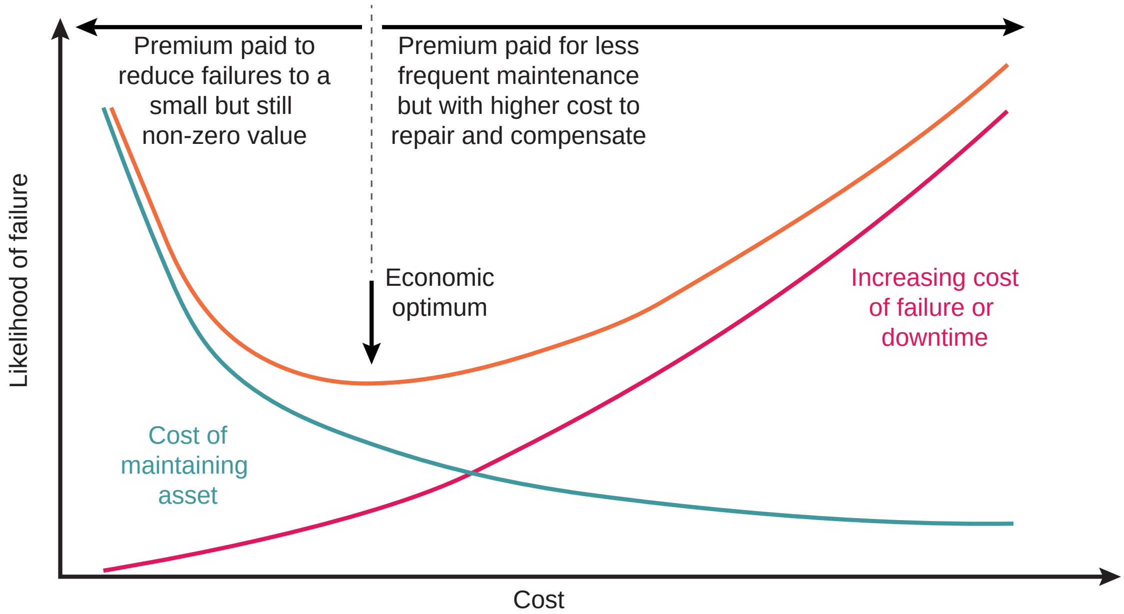


Figure 2 – the economics of remote condition monitoring can be quite complex.



open switch and the adjacent stock rail, which would interfere with the movement of the points. An excessively high ballast shoulder must be brought down to an acceptable height, to reduce the risk of pieces of ballast obstructing the movement.

The identity of the points and more specifically the operating mechanism is indicated at some suitable position on or adjacent to the points. In the UK, by convention the identity plate is fixed on a sleeper close to the toe of the points on the side nearest the normally closed switch. Though a seemingly minor matter, the presence, legibility and correctness of the points' identity is crucial for accurate communications and safe actions during engineering works and when operational issues make it necessary to move the points manually.

In track circuited areas the stretcher bars and other lateral fittings are fitted with insulating layers to prevent a short circuit across the rails. These insulations must be checked for presence and good condition to minimise the risk of a track circuit failure.

Finally, and most importantly, we consider the maintenance of the point operating mechanism itself. If there is one test that is common among various types of point operating mechanism it is the Facing Point Lock (FPL) test. This test is designed to prove that the points can only be locked on the ground if the closed switch is within an acceptable distance (3.5mm being typical) of its fully closed position at the toe of the points (for safety) and are guaranteed to lock if the measurement is typically not more than 1.5mm (for reliability). The test is made typically by inserting a 3.5mm gauge between the switch and stock rail in line with the first slide chair bolt and moving the points manually towards it until the lock jams. The test is then repeated with a 1.5mm gauge in the same position to prove that the lock engages. If either test fails, and provided that the S&C has been verified as in good order, an adjustment to the lock mechanism will be required.

In a similar vein to the FPL test is the detection test, which in theory is carried out in the same way but using 3.5mm/5mm gauges. This test would be naturally hindered by the action of the lock, and so is carried out either by 'floating' the lock (compensating for the detection gauge by moving the lock out of the way) or by using slotted gauges that can fit around the detector rods and displace them by the required distance (3.5mm to achieve detection, 5mm to break detection).

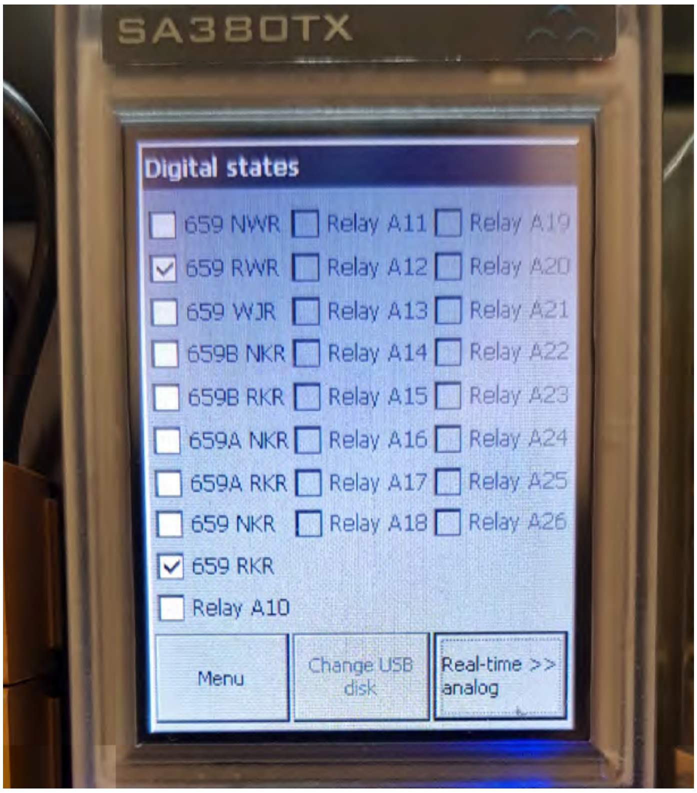
The specific maintenance tasks on a point operating mechanism itself vary considerably from machine to machine depending on the type of drive used and the locking/detection method. In general they will entail checks on the physical condition of the machine and drive, its fastenings, lubrication, fluid level for hydraulics, and mechanical wear on facing surfaces. Different lubricants might be required, or none at all, according to the type of mechanism involved. A drive-train of gears could require a different grease from that required for the drive rods - and will certainly be different to that applied to the slide chairs!

Detection mechanisms usually rely on some form of electrical contact being made, either microswitches or open contacts. These are frequently the cause when a detection failure occurs and therefore must be checked with gauges as part of routine maintenance. Either a distance gauge is used (in the case of microswitches) to determine the points at which they 'flip' between their two states or, in the case of open contacts by using a spring tension gauge to check the force holding the contacts closed. Other contacts for controlling the motor or clutch mechanisms might also require checking in a similar manner.

Using remote condition monitoring to optimise maintenance

The traditional preventive maintenance we have described uses time intervals between maintenance events that is based on the likelihood of failure and maintaining a high level of confidence in the safe functioning of the assets. There are several reasons why this approach is not optimal, including the labour-intensive nature of the work, the cost of possibly unnecessary maintenance activities, the risk to staff working trackside, and the reduced availability of the assets for service.

A modern, efficient railway needs a more intelligent approach and a different philosophy. From an economic point of view, there is an optimum point where the level of maintenance has minimal adverse business impact (see Figure 2). Maintaining an asset too often is expensive, disruptive to the operation of the railway and may cause more failures because personnel are examining equipment and possibly interfering with what was a perfectly operating point machine. On the other hand, maintaining too infrequently will indeed lead to an increase in failures and consequential cost penalties.



Above, a current clamp of the type used for remote condition monitoring of AC-driven points.
Right RCM data logger display.

What is needed is a system that will allow maintenance intervals to be optimised. Ideally these intervals would be longer than those traditionally used, but more importantly they would be both adjusted and adjustable to achieve cost, safety and availability requirements. This could in theory be done manually by making repeated measurements of the operation of the points and plotting them on graph paper in order to determine acceptable maintenance intervals, but that would clearly be a somewhat "trial and error" process, involving even more work at the trackside to collect the data.

Fortunately, developments in sensor, digital processing, storage and communication technology have brought about a range of different remote condition monitoring products that can measure key parameters of points operation without the need for personnel to repeatedly go onto the track. Note, by the way that we use the abbreviation RCM for Remote Condition Monitoring here, not to be confused with Reliability Centred Maintenance.

It is now possible to measure a point machine system very comprehensively, using such parameters as:

- Load or force on the drive rod (trackside load cell).
- Displacement (distance travelled, trackside sensor).
- Motor current and voltage (sensors in the location feeding electric power to the motor).
- Hydraulic pressure and oil level (already provided on some power packs).
- Detection lost and gained (contact event monitoring or current sensors).
- Rail temperature (sensors on rails).

Measuring many of these parameters requires direct intervention in the point operating mechanism, which could make it more difficult to maintain or renew, thus defeating the objectives of RCM. In the early part of this century Network Rail ran a trial at Peterborough Training Centre, Cambridgeshire, UK, to determine how accurately just one factor, namely motor current, could be used to determine the overall condition of the points from a reliability perspective. The apparent success of this trial meant that most other factors would not need to be fitted in future systems, although voltage readings are still useful for calculating power consumption and detecting a failing battery or supply.

Detecting motor current requires no direct connection to the points circuits and can be done with sensors clipped around the power supply wiring. Where discrete circuits are used to drive the points in each direction a separate sensor is required for each circuit, which can also be used to determine the driven direction. Where three phase supplies are used one sensor is required for each phase and must be connected before the power switching relay, otherwise the phase reversal used to change the driven direction can also upset the calculations made by the data logger, especially if a voltage sensor is being used to calculate power consumption as well. Voltage, current and detection event monitoring can all be performed away from the trackside and are therefore ideal parameters to be used.

A data logger is used to monitor and buffer a set of samples from its sensors, usually at about 100 samples per second, on a rolling memory basis until a trigger value is reached (usually the current at the start of the point movement). From then on it will keep some of the samples already taken and record the current for the duration of the movement before sending all this data to a server for storage and analysis.

Timing detection events, from the loss of detection (e.g., when the points are commanded to move from normal to reverse) to gaining it again (when reverse detection is obtained), is a simple indicator of health when plotted as a trend over time. Statistically significant variations from the usual time can be raised as alarms (e.g., 1.5s longer than usual), particularly if there is a consistent and progressive change seen over time. However, this is also quite a 'blunt instrument' means of monitoring health, and gives little indication of the stress the points might be experiencing as they move.

Motor current is another good indicator of the health of the points. The more stress the machine is under to move the switch rails, the greater the current drawn will be. When plotted graphically it is possible to identify the key stages in the

The example RCM plots above show a normal (top) profile for points movement, and the profile where there is an issue to be rectified, with far more power required to complete the movement.

operation such as initial motor inrush, unlocking, travel, locking and braking/stopping. Excessive current levels compared with that considered 'usual' for each point machine can be used to trigger alarms and bring the equipment to the technician's attention. The analysis and raising of an alarm has evolved and improved over time because the difference between a slightly outlying but correct operation versus a developing fault can be subtle, and barely detectable by simple threshold detection. It can also result in a lot of false positives that can undermine confidence in the RCM system. Some companies have developed machine learning algorithms to help distinguish between these, so as not to bombard the technician with information that requires a great deal of experience to interpret and understand.

Calculating power consumption can be a slightly more accurate and informative parameter, but it requires a voltage sensor that measures the variations which occur under load. A plot of instantaneous power (the power consumed at any given instant) can be converted into a measure of total power consumption by calculating the area under the graph. The resulting value can then be added to a scatter graph or similar to observe progressive changes over time.

One further benefit of RCM is that it demonstrates when maintenance has been effective. If the points are observed by RCM to be going out of specification, an additional maintenance activity can be scheduled, which should bring the points back to within normal operating parameters. Using RCM it is obvious when this has happened as the graphs and plots will show an immediate improvement in operation time, power consumption etc. If this does not happen it could point to other causes that need to be investigated.

In the past RCM has been seen as associated specifically with signalling personnel, so it has been difficult to get some track personnel to agree a diagnosis when the data suggests a P-Way/S&C problem. Hopefully this is changing and a spirit of co-operation, together with the open sharing of this data, will bring about a united approach to improve points performance for the benefit of everyone.

About the author

Trevor Bradbeer BSc (Hons) CEng Cert Ed MIRSE, started his career as a trainee technician with British Rail in September 1985. In 1988 he started teaching basic signalling, telecoms and electrical principles at the Ilford Training Centre. He went on to various roles in the London area before returning to training and competence management.

In 2004 when maintenance transferred to Network Rail, Trevor stayed with Balfour Beatty working in projects involving computer-based signal works testing and remote condition monitoring, evolving from relay data loggers to leading-edge condition monitoring systems. He completed a software engineering degree in 2003, became a MIRSE in 2006 and gained his CEng in 2013. He also spent several years on points RCM projects for SMRT/SBS in Singapore and MTR in Hong Kong. In 2019 Trevor retired but still works for Signet Solutions in Derby, providing training and consultancy services.