SUMMARY

The purpose of this paper is to present an outline of the strategy Australian Rail Track Corporation (ARTC) implements for the maintenance and upgrade of the trackage infrastructure on its national network. ARTC’s approach to railroad infrastructure maintenance is founded on a “back-to-basics” philosophy that was established and successfully developed and implemented in Victoria, Australia since 1999 to upgrade and sustain the railroad infrastructure thereby increasing network reliability and capacity.

The approach developed, and documented, by Mr Malcolm Owens is the Five Step Holistic Approach to Track Maintenance and upgrade. This paper will review and expand upon this strategy and its implementation and success.

ARTC’s infrastructure maintenance costs are low compared to other benchmarks in Australia and overseas and this is a reflection of putting into practice a “back-to-basics” approach to infrastructure management that is cost effective, easy to understand and sustainable.

1.0 INTRODUCTION

The paper will present an argument that the guiding principles required for railroad infrastructure maintenance to be active, predictive, effective and cost efficient is for the maintenance to have a defined strategic direction and to be:

- Based on basic and easy to comprehend principles;
- Outcome driven not resource driven;
- Planned on a Corridor basis not a discrete location basis;
- Implemented according to an agreed Plan;
- Low in the Reactive component;
- Scoped to achieve desired Outcomes
- Innovative to constantly improve Productivity;
- Delivered according to an agreed Budget;
- Delivered to defined to an agreed Quality;
- Driven by Key Performance Indicators;
- Audited to confirm Outcomes.

ARTC, together with its Maintainers, working in an Alliance, operate using the strategic direction provided by the 5 Step Holistic Approach for the track structure together with these guiding principles listed above to ensure that the agreed maintenance outcomes are achieved.

2.0 TRADITIONAL RAILROAD INFRASTRUCTURE MAINTENANCE PRACTICES

In the past, and even today in many railroads the traditional maintenance practices remain relevant. Many railroad maintainers model their maintenance strategy on what is termed a ‘traditionalist’ infrastructure maintenance application. The traditional approach is centred about breaking the corridor into maintenance manageable discrete sections (or ‘lengths’) and an individual group given responsibility for those specific sections or lengths, whilst a roving project team undertakes responsibility for Major Periodic Maintenance (MPM) project work, such as tie renewal and rerailing.

Even though there are defined operational requirements and standards for each type of mainline track, on many railroads routine maintenance works are regularly planned and undertaken on a section basis without
a strategy that is applied consistently over the entire corridor length. Thus over a corridor there may be considerable difference in the outcome of the maintenance and even the resultant standard of the infrastructure due to differing priorities of the individuals responsible for each specific section.

An example of the traditional approach can be shown by the relationship that exists between track and adjacent drainage works. Generally, track and adjacent drainage works are regarded as routine maintenance and the works undertaken are solely at the discretion of each Team in each section, and therefore the maintenance outcomes are often highly variable. Similarly, some sections of track may remain mechanically jointed whilst other sections are continuously welded due to a section management engineering desire or local strategy for dealing with specific problems.

The traditional approach provides no overall corridor strategy that is aimed at bringing the corridor infrastructure up to a pre-determined commercially driven performance levels that will ensure the reliability, capacity and economic viability of the corridor meets the customers’ requirements. Under the traditional approach, whilst MPM works are undertaken cyclically (typically ballasting, retieing and rerailing) most other work is left to the section team to organise and undertake using its own resources and prioritisation.

Often using the traditional approach to routine maintenance and MPM works, there is little co-ordinated approach or planned cohesion to ensure that the infrastructure works holistically. Whilst a maintainer may have a desire that an entire mainline track be converted from wooden to concrete ties, activities in each section are often undertaken on a disaggregated basis due to the traditionalist approach. As such, widespread disconnections are created in the track. Typical and unfortunate results from the traditional approach that are common in Australia include:

- Ties that are of variable strength and mass from each other being inserted into the track resulting in highly variable track modulus – it is common on some corridors that many sections of track have steel and concrete ties interspersed with the original wooden ties;
- Track drainage that is left unattended and hence results in variable track support mechanisms and the ability to transfer and accept loads, further accentuating the variables in track modulus;
- Rail fastenings that are variable throughout the track, often with adjacent fastenings being resilient or loose dog spikes and anchors, further creating variables to track modulus and track lateral strength;
- Rail joints that are a mixture of welded and discontinuous mechanical (plated) resulting in impacts and stress raisers causing track instability and variable track modulus;
- Rail surface that is variable with uncontrolled cross sectional profile resulting in higher rail wear and additional lateral loadings due to truck steering problems; and,
- Rail surface with longitudinal roughness from corrugations and peaked and dipped welds resulting in rail fatigue and additional impact loading into the track structure.
- Discipline demarcation between track & civil works and those of signals & communications. This results in work being overlooked, not reported and left undone in all disciplines due to the attitude of “It’s not my job….”

The consequences of the above result in the necessity for a continued high maintenance input and a growing, rather than reducing, recurrent cost base for maintenance works.

3.0 ARTC’S DEFINED CORRIDOR STRATEGIES – OUT WITH THE TRADITIONAL APPROACH!

ARTC’s approach is to apply a planned and consistent maintenance strategy across the entire corridor. That means a strategy that co-ordinates and prioritises work practices over the entire corridor to bring the whole corridor up to one consistent and acceptable standard, whilst eliminating or minimising the problems outlined above. This approach minimises the maintenance input and cost and lifts the infrastructure reliability of the network.

Whilst responsibility for a section of track may be allocated, the traditional approach often promotes the demarcation problem and the lack of a holistic view of the infrastructure’s maintenance needs to improve reliability and capability.
ARTC has found that the lack of a defined responsibility for the performance of the overall railroad corridor provides for an infrastructure that is of variable quality and requires maintenance resources much higher than is necessary.

ARTC therefore sets a corridor wide strategy and develops its maintenance plans around the defined and documented strategy. Network-wide, the strategies are the same except that priorities will differ due to the current and actual state of the asset.

ARTC has developed and implemented Strategies that are defined for:

- **Track & Civil Maintenance**
  - *Five Step Holistic Approach*

- **Signals & Communications**
  - *Fault Reduction Strategy*
  - *SPAD reduction Strategy*

- **Bridges & Structures**
  - *Capability Strategy*

This paper concentrates on a review of the Five Step Holistic Approach to Track Maintenance and Upgrading, with special mention of the necessity to ensure track drainage maintains a high priority.

### 4.0 THE FIVE STEP HOLISTIC APPROACH

The *Five Step Holistic Approach* is based around managing the track as a system and not as individual components. Each of the components of the system interacts upon each other. Strengthening only one component of the system to a level well beyond the strengths of the other components will provide only incremental and inefficient overall strength improvement. Practice has shown that strengthening one track component only may degrade that component and other track components quickly resulting in overall less track strength and capability.

To strengthen track effectively and cost efficiently so it behaves predictively, the effect of improving only one part of the track structure needs to be reviewed with respect to its effect on other components of the track structure. Often, the effects on other components will result in their rapid degradation unless corrective action is undertaken.

The *Five Step Holistic Approach* requires each of the components of the track structure to be evaluated and remain in harmony strength-wise, with each other, so as to ensure overall predictive behaviour. It is inefficient and wasteful to have any component of a greater comparative strength than other components of the track system.

The five critical elements of the track structure to be harmonized to ensure predictable track behaviour include:

**Rail**
- Sufficient strength to carry the axle load required
- Rail head smooth and free of defects > 0.15mm in height or depth. This reduces P1 and P2 impacts into the rail support structure;

**Fastenings**
- Need to be resilient to provide track continuity and both lateral and vertical rigidity. Resilient fastenings also improve track modulus and therefore load and speed capability.

**Ties**
- To be adequate in strength to transfer the load from the rail to the ballast.
- To be spaced sufficiently to prevent excessive rail bending.
- Be of uniform spacing to uniformly transfer the load
To be uniform in bending strength, size and mass so as to transfer a uniform load to the ballast and formation.

**Ballast**
- Not to hold water so as to carry the load from the tie to the formation
- Be of sufficient depth to spread the load to the formation to prevent localised formation failure and the formation of ballast pockets in the formation.

**Formation**
- To not hold water and be well drained and capable of accepting the load
- Ensure water runs away from the track formation and not into it.

The *Five Step Holistic Approach* requires the overall capability of the final track to be determined as a Track Modulus value. Track strength is determined as Track Modulus – measured as deflection of the track for a given load value. The track is required to have a minimum Track Modulus to meet the requirements of the loads applied to the track.

A track structure with a low track modulus will become unstable quickly. High track modulus infrastructure will maintain its rigidity but the track components may wear quickly, especially rail due to high rigidity, e.g. rail on concrete tied or concrete plinth track is more susceptible to wear than rail on wooden ties given a similar maintenance effort. There is an optimum track modulus range that track should be sustained at to minimise wear and maintenance input and provide predictable behaviour.

### 4.1 Case Study Example

A simple replacement of wooden ties with concrete ties with minimal other works, has found that:

- Whilst the heavier concrete ties will initially improve the track strength, if the impacts generated by rail head discontinuities such as corrugations and peaked/dipped welds are not removed this will damage the ties, pulverise the ballast and generate track instability.
- If drainage of the ballast and formation is not improved, the heavier concrete ties will simply sink into the ballast and create mud holes and track instability.

**Example solution:** When upgrading track with concrete ties:

- Ensure that the rail head is smooth by grinding and weld straightening if necessary (<0.15mm discontinuities);
- Ensure ballast is adequately drained and of sufficient depth and strength to transfer and spread load to the formation;
- Ensure formation is adequately drained and does not hold water and has sufficient strength when drained to accept the load.
A common oversight by many railroads when installing concrete ties is not to address rail smoothness and drainage – This is often a mistake made by railroad engineers where concrete ties are installed in lieu of wooden ties. Wooden ties are much less rigid than concrete ties and will absorb, or even mask, poor running rail surface. Concrete ties tend to accentuate the rail roughness due to their overall higher mass and flexural capability.

When track has variable capability tasks, from the high axle loads and train frequency such as on coal and mineral lines to the low frequency medium axle loads on lines of less demand, it is appropriate to vary the priorities within the implementation of the 5 Step strategy, but not the strategy itself. The desire is to raise each track up to the required capability level and keep it sustained at that level for the minimum recurrent maintenance cost.

For example – High volume mineral lines need a priority on elimination of impacts into the track structure emanating from rail roughness. Additionally, it is paramount to maintain a stable and uniform track modulus so all ties need to be equally spaced, have the same flexural capability (so uniform size and material type is important) and the formation needs to be able to accept this uniform load in a manner that does not promote non-uniformity. So therefore mud holes and ballast pockets need to be addressed and a plan put in place to eliminate these on a priority of effect basis before the traffic task overtakes the maintenance effort and the track falls into disrepair and speed restrictions need to be imposed.

On lighter lines, the priority is less about rail roughness (although this will need to be addressed) but more on raising the whole of the track modulus so as to permit an immediate reduction in maintenance input. ARTC’s priority therefore is for uniformity in tie type, together with whole scale improvements in track, ballast and formation capability.

Over the past 5 years across its network, ARTC has taken the approach that infrastructure works and projects were undertaken to bring the track up to the necessary capability level as determined by the Australian Transport Council (ATC) in November 1997.

Other works undertaken at the same time as part of the holistic approach were designed to enable the attained capability to be sustained at a progressively lower cost.

Track capability on the entire ARTC owned and leased network has been raised to the ATC standards and sustained since the year 2000. The ATC Standards relate particularly to axle load and speed combinations and include:

- 23 to 25 Ton Axle Load @ 50 mph
- 21 to 23 Ton Axle Load @ 72 mph
- Less than 21 Ton Axle Load @ 81 kph

5.0 IMPLEMENTATION OF THE FIVE STEP HOLISTIC APPROACH

ARTC initially implemented the Five Step Holistic Approach specifically on its recently acquired property in the state of Victoria, Australia in 2000/02, and has rolled out this strategy as the basis of all track maintenance and upgrade on its network since late 2002.

For the initial implementation in Victoria, this approach was most successfully used on the 200 mile North East Line (Melbourne to Albury) and a concrete tie section on the Western Line (Gheringhap to Ararat) of about 100 miles in length.

North East Line: The original track structure consisted of 94 lb rail, spiked and anchored to wooden ties on a bed of fouled ballast that ranged from 1" to 4" thick below the tie.

Western Line: The track structure was second hand worn 94 lb rail on new concrete ties placed on a bed of fouled ballast with depth ranging from zero to 6" deep.

In both cases the side ditches (cesses) were fouled, the formations were generally wet and not free draining, and the fouled ballast was holding high quantities of water, hence mud holes were plentiful.
The dilemma – given the available modest budget, how can we achieve ATC Standards? Due to funding constraints, track could not be rebuilt, nor could it be undercut for long distances.

A review of the track strength required to carry and sustain the ATC Standards was undertaken and was determined that for 94 lb rail on ties spaced at 25 inch centres the required track modulus was 17MPa. The existing wood tie track had an estimated 12MPa strength due to poor formation; poor ballast condition and water in the ballast; tie condition and spacing; anchor condition; and rail weight.

A further dilemma – What part of the track do we improve to achieve a higher track modulus? Is it the rail, anchors, ties, ballast or formation? One or all of these track components?

A review of each of these components was therefore undertaken to determine the best combination of works to carry out that would achieve the minimum required track modulus.

**Rail** – Whilst heavier rail, such as 132 lb rail, would provide an immediate increase in track modulus of around 4MPa, and was readily available, the cost to procure and install was prohibitively expensive. The existing 94 lb rail was advised to be “life expired” due to increasing breakages, corrugations and numerous peaked and dipped welds, however it was only 60% to 70% worn. Could life be brought back to this rail?

**Fastenings** – The existing spikes and anchors were not holding the rail, with typical movement of rail with the passing of a train, of more than ½ inch through the tie baseplate. The Fair Type anchors were clearly not working, and most of the spikes were loose. As the line is bi-directional, the rail movement was in both directions and gave a very unpleasant feeling of instability. A derailment waiting to happen?

**Ties** – Tie condition was exceptionally variable. The previous owner had skipped a number of tie cycles so the average tie age was approaching 19 years. Tie spacing was also variable and typically averaged 25 inches, although there was bunching and separation in many clusters. How can the ties be improved to provide a sustained increase in axle load and speed?

**Ballast** – Whilst the track was only 40 years old and had only carried around 55MGT, the ballast was fouled and shoulders were blocked. In most places there was more water in the track than in the wayside ditches, and mud holes were frequent and extensive. This was certainly pulling the track modulus value down, but what to do with such an enormous quantity of fouled ballast over the 200 miles length?

**Formation** – The NE Line track, whilst being a bi-directional standard gauge line, was located immediately adjacent to a low use broad gauge 5’3” line, that was also full of water and has a different owner. The formation was saturated and being fed from the adjacent track. Could this ever be corrected within the budget constraints and sustained?

Clearly it was not feasible to make only one correction to a track with so many problems. Whilst heavier rail and a dense tie replacement cycle would achieve the track modulus required this would not achieve the sustainability requirements that we required.

**The Dilemma’s Solution**

This is where the concept of the 5 Step Holistic Approach was born. It was obvious that a ‘whole of track’ approach was required, hence ‘holistic’, and it was also apparent that each of the five components of the track – rail, fastenings, ties, ballast, formation, all needed attention. To attend to one or two or even three items only would not allow a sustained track strength to be attained, hence each component needed to be attended to.

**Rail Solutions** – Remove the impacts generated by the rail by removing the corrugations and the peaked and dipped welds. Additionally, if the trains are steered better this would reduce the lateral loading on the rail and the subsequent stress on the rail and track structure. By removing these impact generators, this would reduce the amount of stress within the rail and also the amount of impact entering into the track structure. A contract was therefore awarded to Loram and Harasco to re-profile the rail by grinding, and remove dipped welds by discrete in-track rail bending and rail grinding.

This process on the rail saw a 92% drop in broken rails in the first 18 months after grinding and straightening, and is still sustaining an annual 60% drop in rail breaks. Refer to Rail Breaks chart.
Additionally, with the removal of impacts into the track structure from corrugations and peaked and dipped welds, the frequency of tamping has decreased by more than 300%, although other factors, such as improved drainage and better ties contribute to this.

**Fastening Solutions** – Clearly the fastening system of spikes and anchors was not working as this arrangement was permitting the rail to move longitudinally and provided no lateral track stability. It was therefore determined to install resilient fastenings to the entire track. The chosen fastening system (from international tender) was the Rex-Lok system as this could be retrofitted to the existing tie plates, and spikes could be changed out for springspikes (lockspikes).

The effect of resilient fastenings was to improve lateral resistance, increase the Track Modulus by 3 MPa, and enable to rail and ties to work as one.

**Tie Solution:** Extensive tie replacement and re-spacing of ties was undertaken, using standard wooden ties.

**Ballast Solutions** – As it was beyond our financial capabilities to replace or undercut the ballast on a wholesale basis, some lateral thinking was required. What makes an ideal support mechanism for track? In reality it is not single sized, rough edged stone, but a well graded medium that can be packed under the tie for support. Ballast is generally uniform in size for long term drainage purposes, not for support purposes, hence a fouled ballast should be satisfactory for support if it is kept dry. As water will mobilise and lubricate the interstices of a the ballast particles and therefore create track instability, if fouled ballast can be kept reasonably dry, in theory it will work satisfactorily.

A program was established to begin draining the ballast. A Loram shoulder cleaner was brought in from the USA – the first shoulder cleaner ever to come to Australia, and it cleaned both track shoulders. An amazing sight as water literally flooded from the track in many locations even though the surrounding area was dry.

As a supplement to the shoulder cleaning, Mr Darrell Cantrell (Cantrell Rail Services Inc) advised on drainage issues and brought with him his concept and culture of “Drainage, More Drainage & Better Drainage”. Under Mr Cantrell’s direction, thousands of cross drains through the ballast and deep into the track structure and guided away from the track, were installed.

The resultant from these works has been a life extension of ballast by up to 10 years and the ability of the track to hold both top & line for extended periods.

**Formation Solutions** – As a dry formation will transferred track load to be absorbed more readily without deformation, activities similar to ballast drainage were undertaken. In particular, deep cross drains were installed in an attempt to access and drain ballast pockets that had developed in the formation and created instability. Additionally, the track side ditches (cesses) were cleared, cutting ditches cleaned out and deepened, and the side track verges and access roads were graded away from the track. As part of the training of staff, they were taught the simple concepts that:

- “Drains need unblocking” and…….
- “Water runs down hill”

**6.0 FIVE STEP OUTCOMES**

Has the 5 Step Holistic Approach worked? The following benefits are currently being enjoyed:

- ★ Rail breaks initially down by 92% per annum and being sustained at rates 60% per annum better than Year 0
- ★ Tamping reduced by 300% from Year 0
- ★ Track faults reduced by 65% from Year 0
- ★ Signal Faults reduced by 15% from Year 0
- ★ Zero track buckles in 4 years since work completed compared to average of 4 per annum.
- ★ Axle load increased from 19 tonnes to 23 tonnes
- ★ Speed increased from 55mph to 70mph for freight trains
- ★ Speed increase from 60mph to 80mph for passenger trains

Clearly the outcomes from using a structured approach like the 5 Step Holistic Approach has worked.
7.0 CONCLUSION

ARTC’s track infrastructure maintenance strategies are principled on a “back-to-basics” approach. The *Five Step Holistic Approach to Track Maintenance* is a commonsense approach to track management – treat the track as one whole structure not individual elements.

The approach that ARTC take to the management of signals and communications, including SPADs due to infrastructure is also structured and readily understood and embraced by the staff and maintainers. Whilst not elaborated in this paper, ARTC’s back-to-basics approach has achieved outstanding efficiencies and safety.

As well, ARTC’s bridge and structures management reflects a modern, cost effective and safe approach to these critical elements of railroad infrastructure.

ARTC’s mainline railroad infrastructure maintenance costs are much lower than that of all other railroads in Australia, and this is a reflection of putting into practice a “back-to-basics” approach to infrastructure management. As traffic on the ARTC network rises, so will its maintenance costs, but not in a linear manner but in a planned and controllable way, because the maintenance input requirement can be predicted, scoped and controlled for outcomes required for all aspects of the railroad infrastructure.
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Rail Defects

Trend in Signal Failures 2001-2004

TCRS - Vandalism, unknown, Train control error, outside ARTC control, Other contractor, Operator, Operation as Designed, Natural Causes, Maintenance Related, Equip/Infra Failure

ENGINEERING & INFRASTRUCTURE
Average Number of Minutes for Train Delays per 10,000 '000GTK