NETWORK

Annex V

(Confidential) Worley Parsons – Benchmark Heavy Haul Lines: International and National Comparison, 18 August 2008

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resources & energy

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EcoNomics

QR NETWORK

TTCI Transportation Technology Center, Inc.

UT3 Parallel Active Comparison Exercise

Supporting Document

Benchmark Heavy Haul Line

International and National Comparison

301001-00190

20 June 2008

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SYNOPSIS

As supporting documentation to UT3 parallel active comparison exercise Queensland Rail Network commissioned WorleyParsons to carry out a national and international benchmarking study about two main topics relating to maintenance of heavy haul railways:

- Track and Structures
- Costs and Processes

WorleyParsons sub-contracted Transportation Technology Centre, Inc. to help with the international aspects of the track and structures benchmarking.

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EXECUTIVE SUMMARY

Queensland Rail (QR) Network Access commissioned WorleyParsons to carry out a benchmarking study in order to compare QR to other national and international heavy haul railway lines. The focus of the study covered two main areas; track and structures, and cost and processes.

Queensland conditions are fairly unique when compared to those experienced by other railways, which made certain areas of the study difficult to definitively benchmark. In these areas, specific studies into climactic and usage differences could yield clearer results. Overall, however, the study found that when benchmarked against a number of national and international railways, QR was neither significantly worse, nor better, than the comparison subjects.

Key findings from this report include:

- QR's accepted engineering processes, standards and methodologies for the asset management of track and structures infrastructure was found to be comparable to international best practice, and in some cases, more advanced than those adopted by other heavy haul railway operations.

- QR's costs were found to be considerably higher in some instances but also significantly lower in others when compared to other operations. Where QR costs were higher, without exception the reasons were due to conditions imposed on the network by the nature of the coal supply chain function, or due to inclement and / or inherent environmental conditions[1].

- QR's management processes differ to the railways benchmarked, due in part to inherent differences in cultural and organisational structure. Successful management is very much reliant upon culture and ethos with results considered subjective dependent on the organisation's objectives. QR services both international mineral supply chains as well as providing a community service. Although this review focuses on the QR Coal System, it is fair to say that much of the cultural and ethical foundations which form the basis of how the network is operated developed from an organisation which was also built to provide an essential community service. History has shown that there are benefits and constraints to this approach and it is not considered appropriate to apply generic evaluations of which is 'better' or 'superior' without considering all the externalities, social and cultural factors.

[1] For example steep slopes and unstable embankment materials, black soils, etc.

Track and Structures

- QR is not the only heavy haul railway with narrow gauge track. Maximum axle loads on the railways that participated in the benchmarking study tend to increase with track gauge. QR's 26.5 tonne axle load on track with 1067 mm gauge is consistent with accepted engineering practices for that gauge.

- QR's maximum operating speed for loaded trains of 80 km/hour is one of the highest in the railways that responded to the questionnaire. The operation of high speed passenger trains on some parts of the QR network puts further demands on maintaining good track quality.

- Due to the relatively low axle loads and high annual tonnage on the Goonyella system there are more wagon journeys than on most other participating railways.

- The sleeper spacing used by QR is wider than on other railways, but it is consistent with the relatively low axle loads and the use of concrete sleepers.

- The number of turnouts on QR is close to the average for all railways that took part in the survey. QR's exclusive use of swing-nose crossings should result in relatively low turnout maintenance costs.

- The ultrasonic testing interval used on the Goonyella system is longer than on other railways. However, the rail failure and defect rates, and the rail life on straight track is better than on other railways. Regular measurements of rail wear and the information from monitoring sites enables good decisions to be made on rail renewal requirements. QR has excellent processes for monitoring rail wear hence enabling them to increase the amount of permissible rail wear, thereby extending rail life.

- Although the track geometry recording interval on QR is longer than on other railways, the plain line tamping interval on QR is similar to other railways. The average gross tonnage between ballast cleaning operations on QR is similar to the average for all the railways that provided this data.

- The ballast cleaning interval on some parts of QR is relatively short. QR monitors ballast pollution by measuring percent ballast contamination. This helps to ensure ballast cleaning is only performed where and when necessary.

Signals

No benchmarking was able to be undertaken due to insufficient asset management information made available in order to perform an effective comparison. In addition, the signalling assets were at or near their end of life and due for replacement in the near future. The age of the life expired assets makes it difficult to compare against more recent technology.

Communications

The biggest issue for communication network designers and managers is the rate of change of technology. Benchmarking technology choices and the maintenance costs associated can therefore only be achieved for systems of the same age. In comparison, we found that other major national railways have similar approaches, technology and systems' age to that of QR.

Power

QR could not provide sufficient power asset management information due in part to a lack of service statistics recorded since 2004. WorleyParsons was therefore unable to establish the in-service reliability of the existing assets in sufficient quantitative detail.

Costs and Processes

In general, despite expectations to the contrary in some quarters, when compared with railways carrying similar freight in similar conditions, it was found that on average QR costs were not excessive.

- QR's highest maintenance cost item is ballast undercutting, the demand for which is aggravated by extensive coal spillage on the network. However, on benchmarked railways it was interesting to note that despite mitigation measures being implemented, the percentage cost of this item still remained higher than other regular maintenance items.

- It is to be noted that some coal fouling mitigation measures, would potentially involve substantial capital investment by system users. These have to be assessed in relation to the current cost of ballast undercutting, bearing in mind that the benchmarking results indicated that even with some improvements ballast undercutting may potentially remain a major cost item due to the very large tonnages being moved. This would indicate that perhaps no system has found the optimum solution to this problem.

Prior to the resource boom of the last decade QR undertook a comparative assessment weighing up the costs to supply chain efficiency by creating longer journey cycle times through the use of tippler wagons versus the shorter unloading times provided by the use of bottom dump wagons. The result of this assessment formed the justification from which QR made the decision to use bottom-dump wagons on its coal network. To date the supply chain has had the advantage of shorter cycle times.

In response to this problem QR has commissioned the Coal Loss Management Project. On completion of the project, and on substantiation of any benefit cost analysis required to implement solutions, it is anticipated that some recommendations from the Coal Loss Management Project will be adopted. This will help to reduce the impact of the short term maintenance programme as well as achieve long term objectives. Additionally, QR is trialling accepted innovative technologies, like the use of stone-blowing machines, in an effort to reduce costs in the future.

Despite coal fouling causing a significant problem for ballast cleaning, rust and deterioration on the asset caused by the abrasive chemical constitution of coal does not appear to have caused other major problems to rail or ancillaries. This indicates that other programs implemented by QR can be considered adequate and efficient in maintaining the asset as fit for purpose.

Despite relatively low axle loads for heavy haul operations, QR maintained one of the highest annual tonnages. This indicates that the network is operating under relatively harsher conditions in regards to opportunities to conduct routine maintenance procedures and pounding on the assets.

Possessions or “gaps” in operations are essential to conduct these procedures and it is considered that for each task there is an optimum time when these works can be carried out to the greatest efficiency. If the required slots are minimal or perhaps rarely available, then regardless of the planning effort for each task, it will remain fundamentally inefficient as it will not be possible to make optimum usage of mobilised resources.

In critiquing costs it must be noted that QR experiences enduring circumstances such as:

- Significant spillage problems in part to a combination of factors including faulty doors on wagons and poor unsupervised loading and unloading practices;
- Comparatively less available paths for possessions and routine maintenance procedures due to the 24/7 nature of operations, where the traditional ‘peak’ and ‘off peak’ windows do not apply; and
- Cancellation of planned possessions with little mechanisms to encourage supply chain parties to implement planning and implementation of innovative effective systems and solutions to issues.

QR has historically taken the sustainable approach, that is, decisions to improve operations through enhancements and effective maintenance of existing assets rather than through major capital renewal expenditures. During the period that whole of life costs are significantly lower than replacement costs, this approach imposes minimal cost penalties to system users and owners. However, there may be a point in time where such short term savings become costs through inefficient practices (it is considered that advances in engineering and technology can advance this moment immaturely). At this point in time one must decide whether replacement or improvement is the most sustainable option for the future, giving due consideration of predictions for future requirements of the asset when assessing the benefits such investments.

It is too be noted that many mineral booms have ceased suddenly with costly repercussions to investors and infrastructure owners.

1. INTRODUCTION

Purpose

1.1 QR Network commissioned WorleyParsons to carry out a national and international benchmarking study about two main topics relating to maintenance of heavy haul railways:

- Track and structures
- Costs and processes

It was decided to split the study into these two parts because personnel from different sectors, and possibly different levels of management, of a railway organisation would be expected to complete each questionnaire. The quality and accuracy of the responses was also expected to be higher if this approach was adopted.

Benchmark Scope

1.2 The focus of the benchmarking was to compare QR to other heavy haul railway lines with a total length between 100 and 1,000 km. Several factors were taken into consideration when deciding whether to normalise results to account for management of scale. These included:

- All railroad respondents were considered large enough to have similar overheads. Therefore scale was not considered to have a significant effect on the comments and deductions made in this report;
- Analysis and comments on benchmarked engineering processes were focused on specified lines which shared similar freight tasks and construction. The objective was to benchmark behaviours in engineering processes and methodologies. Logically these should therefore not be affected by size and network but rather influenced by best practice;

Hence no normalisation has been made to account for management of scale.

1.3 All statements in this report are about a defined, specific line. The request for information covered 97 questions presented to the participating railway companies in the form of questionnaires. All responses have been recorded, compiled into reference tables and graphs and incorporated into this report for appraisal.

1.4 The major focus of the comparison across all areas is technical and management data rather than costs. Broad details of costs for overall track maintenance have been included in the final section of the report for reference. Cost data is less satisfactory for comparison due to a number of factors including variances between accounting methods, differing base levels of remuneration between countries, allocation of structures costs and international exchange rates. Railway organisations are also very reluctant to answer questions about their costs. When reviewing the results it is important to note that data is presented on a per annum basis.

Railways Invited to Participate

1.5 Questionnaires were sent to the following railways within Australia:

- QR Network, two different lines (Goonyella and Blackwater);
- BHP Billiton;
- Rio Tinto;
- FMG; and
- ARTC Hunter Valley.

The international railways invited were:

- Brazil, VALE;
  EFVM; Estrada de Ferro Vitória a Minhas;
  EFC; Estrada de Ferro Carajás;
- Brazil, MRS;
- South Africa, Transnet (formerly Spoornet);
- Sweden, Banverket;
- Canada, CN;
- USA, CSX;
- USA, BNSF;
- USA, UP;
- USA, NS;
- USA, Amtrak;
- UK, Network Rail; and
- Germany, DB.

In addition, a questionnaire was completed for TTCI's Facility for Accelerated Service Testing (FAST). This is a short, high tonnage, heavy axle load test track. The results from the FAST questionnaire were only used where the length of track had no effect on the answer.

Response

1.6 In general the response was disappointing with only nine of the total number of railways invited having responded. The reasons given are summarised as follows;

- Members of the organisation forbidden to participate in questionnaires and surveys;
- Members of the organisation too busy to allocate time and resources to respond; or
- Lack of trust or fears of commercial sensitivity in divulging the required information.

The latter was particularly apt to the cost and processes questionnaire.

Confidentiality

1.7 All the railways were sent a letter introducing the questionnaires. This letter detailed the conditions under which the survey was being conducted and assured complete confidentially of the participants.

As a reward for participating the railways were offered a summarised copy of this benchmarking report.

Normalisation

1.8 To enable a comparison of indicators relating to track, it is generally necessary to take into account the variables which contribute to such a comparison. The data is normalised with a "normalising factor".

The normalising factor is derived from a formula compiled from experience that basically assumes "average" track has a factor of one (1) and increases or decreases according to the characteristics assumed to affect the maintenance needs. The assumptions can be argued and can be adjusted following further consultation if this is found justifiable. However the use of a standard approach enables comparison and also the ability to understand the components included in the normalising factor. Sensitivity analysis can then be applied to the track factor by altering the constants and weightings within the formula.

It should be emphasised that the track factor is a reflection of the track component standard and does not consider maintenance requirements resulting from the types of traffic usage.

Normalisation Formula

1.9 Normalisation formula = (A + B – C) x D

Where:

A = 1 for average track with average grade, curvature and drainage conditions,

B = an increase to allow for additional characteristics requiring extra maintenance,

C = a decrease to allow for characteristics requiring less maintenance,

D = 1 for standard gauge, 0.97 for broad gauge and 1.03 for narrow gauge.

$$A = 0.75 + \frac{(0.5 \times \text{Track with Poor Drainage}) + (1 \times \%\ \text{Curved Track}) + (0.25 \times \%\ \text{Track Grade} > 1{:}100)}{200}$$

Where: 0.75 is a constant to ensure the result > 0.

0.5, 1 and 0.25 are assumed weightings based on the relative effect the weighted item has on the maintenance effort.

200 is a constant applied to assign a unit value to the average track.

$$B = \frac{(1 \times \text{Length welded turnouts}) + (2 \times \text{Length tunnels \& underbridges})}{\text{main line kms}}$$

Where: 1 and 2 are assumed weightings based on the relative effect the weighted item has on the total maintenance effort.

$$C = \frac{(0.2 \times \%\ \text{of Concrete sleepered Track}) + (0.05 \times \%\ \text{of track with elastic fastenings}) + (0.75 \times \%\ \text{of Track with CWR})}{200}$$

Where: 200 is a constant based on the assumption that CWR on concrete sleepered track with elastic fastenings requires only 50% of the maintenance required for track without these benefits.

Applying these factors produces the following relative maintenance needs for a unit length of track.

Jointed, timber, non-elastic: CWR, concrete, elastic = 2:1

Jointed, timber, non-elastic: CWR, elastic on timber = 1.67:1

CWR elastic on timber: CWR, concrete, elastic = 1.2:1

1.10 Note that the normalising factor takes into account negative influences such as percentage of curves, turnouts, tunnels and bridges as well as positive influences such as concrete sleepers, elastic fastenings and CWR.

When comparing track maintenance, other components used in the derivation of the normalising factor include:

- Turnouts per track kilometre
- Track gauge
- Total underbridge length
- Accessibility
- Traffic density
- Age and condition of asset
- Climate
- Maintenance regime

All these items will contribute to the level of difficulty in maintaining the track system.

Negative Influences

1.11 Table 1 compares for each railway the three major negative influences that will affect the normalising factor.

Curvature has been broadly defined and can be regarded as the percentage of track with curves less than 1000m radius. An increase in the quantity of track stated as “curved” will have a detrimental effect on the final value of the track factor.

The factor that has the most adverse influencing effect on the maintainability of Coal and Mineral track is curvature (the highest for all systems).

Positive Influences

1.12 Set out below is Table 1; Normalising Factors for Participating Railways. It compares the four factors which are considered to require least maintenance effort once installed for each system. Consequently, they would have a positive influence on the normalising factor for each of the comparison railways.

Normalisation Table

1.13 Table 1; Normalising Factors for Participating Railways shows the normalising factors based on the 0 Normalisation formula with its negative and positive factors for the participating railways.

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Table 1: Normalising Factors for Participating Railways

Normalising Process

1.14 Hypothetically, if considering the costs of railways X & Y, where the costs of X are double the costs of Y and after applying a calculated normalisation factor of 2 (i.e. A/B =2) the conclusion is that both the railways have the same normalised costs, this means they are equally efficient or cost effective. If however, somebody challenges the calculation of the normalisation formula and says the factor should be 1.5, the results now indicate that railway X is less efficient than Y. If the factor is challenged again and somebody says it should be 2.5 we now have railway X more efficient than Y. The argument begins to revolve around the normalisation factors and not about the cost data.

Where there is a paucity of data, the above process becomes particularly relevant as the minor differences between the railways being assessed are the basis for most of the discussion. Hence we found that although the normalisation process defined above was applied to all the data, it was found to add little value to some results of the analysis.

In these cases a discussion based on the raw data has been included. These discussions examine the reasons why railway X costs may be double to that of Y, to try and quantify each one. It is felt that these discussions substantiated the results from the normalisation process where the normalisation process alone could be seen as being misleading.

2. TRACK AND STRUCTURES

2.1 This section gives results and commentary on the responses to the track and structures questionnaire (Appendix 1). Several railways did not respond to the questionnaire or only responded in part. Nevertheless, the responses that were received allow for some meaningful observations to be made.

2.2 The greater majority of the participating railroads were chosen specifically for their correlation with the QR coal system (i.e. track structure, nature of traffic, yearly tonnages, etc). Hence most were for heavy haul bulk freight with perhaps a small percentage of passenger trains. QR has the highest operating speed (due to high speed passenger operations) and the lowest axle load.

Track Construction

Track Gauge

2.3 Figure 1 shows that responses were received from railways with various track gauges.

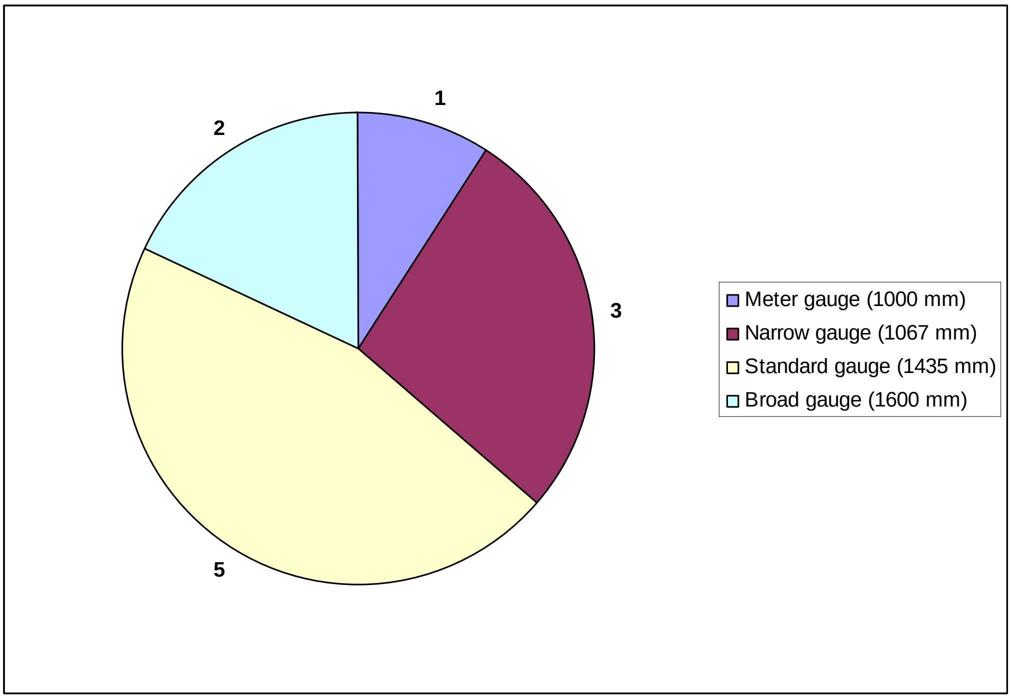

Figure 1: Number of Responses for Different Track Gauges

2.4 Figure 2 shows the variation of track gauge with annual gross tonnes of traffic on the railways that provided this information.

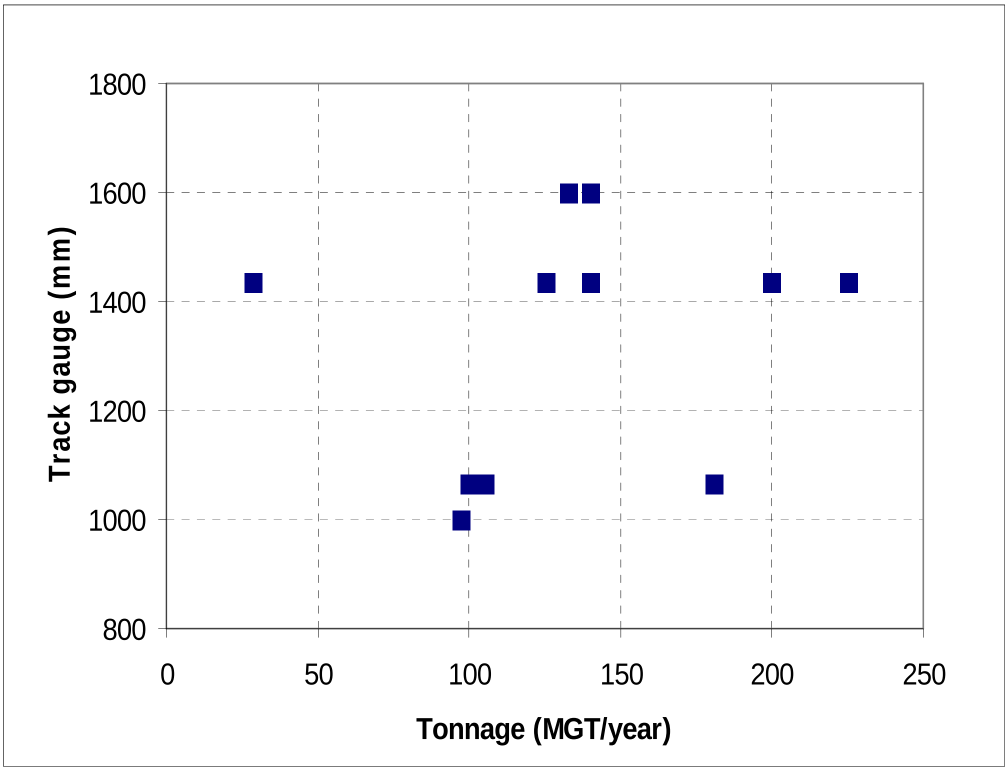

Figure 2: Variation of Tonnage with Track Gauge

It appears from Figure 2 that there is no correlation between the track gauge and the gross annual tonnage. The choice of track gauge depends on the era when the railway was constructed and the gauge of existing railways in the same region. It is also influenced by the anticipated maximum axle load. This figure indicates the variety of gauges used by the respondents and demonstrates that tonnage per year can be autonomous of gauge.

2.5 Figure 3 shows the relationship between track gauge and maximum axle load.

Figure 3 shows that maximum axle load tends to increase as track gauge increases. QR's maximum axle load of 26.5 tonne operating on narrow gauge track is consistent with current international industry practice.

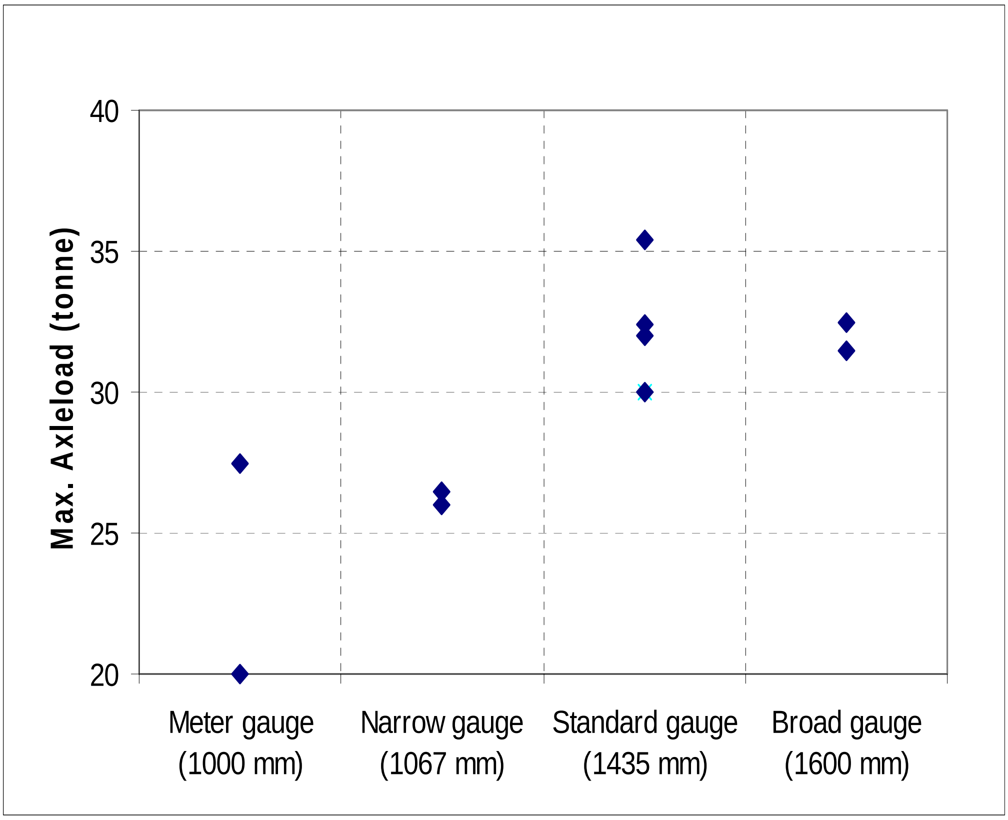

Figure 3: Variation of Maximum Axle load with Track Gauge

Maximum Speed

2.6 Figure 4 shows the relationship between the speed of loaded freight trains and the gross annual tonnage of traffic.

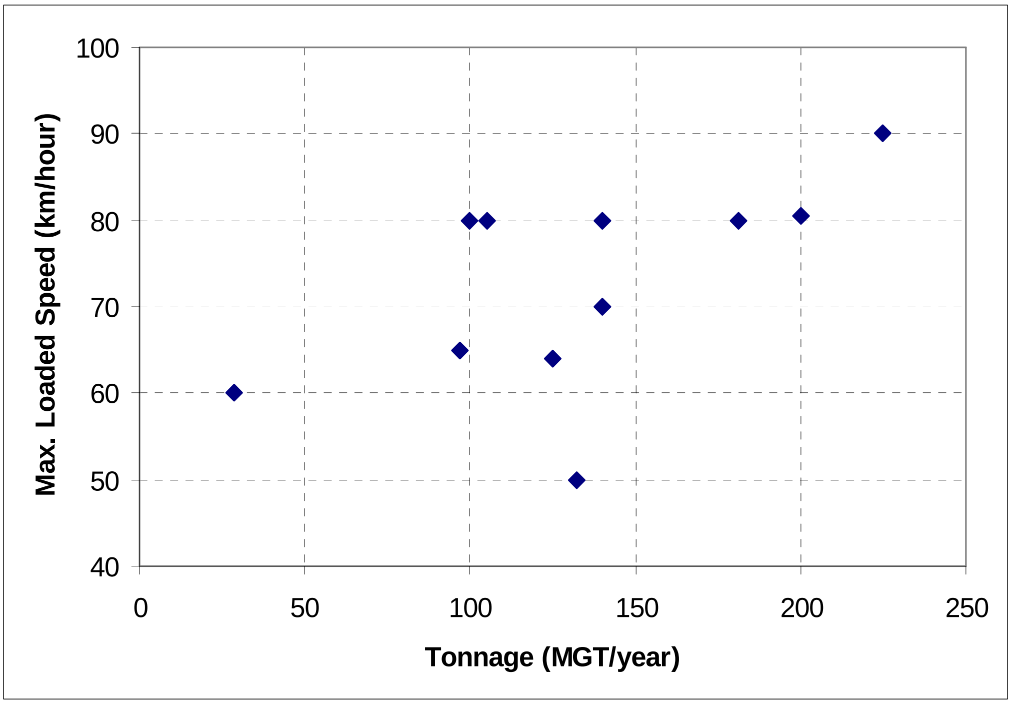

Figure 4: Variation of Tonnage with Maximum Loaded Train Speed

Figure 4 shows there is a weak correlation between loaded train speed and annual tonnage of traffic. This indicates that one way railways achieve high tonnages is by increasing train speeds, thus decreasing overall journey cycles.

Another important factor that affects capacity is the number of tracks. The railways that responded to the questionnaire had a variety of track configurations.

QR's maximum loaded train speed of 80 km/hour, in conjunction with relatively high yearly tonnages, is one of the highest amongst the respondents. This is reflective of QR's objective to increase train path windows through the reduction of total journey cycle times.

2.7 Figure 5 shows the variation of maximum axle load with gross annual tonnage for the railways that provided this data.

Since railways can increase the tonnage of goods delivered by increasing axle loads, a correlation might be expected between these two variables. Figure 5 shows there is no such correlation, however, yearly tonnages are dependent on supply and demand and as this information was not available it is not possible to conclude the influencing factors on the graph outputs.

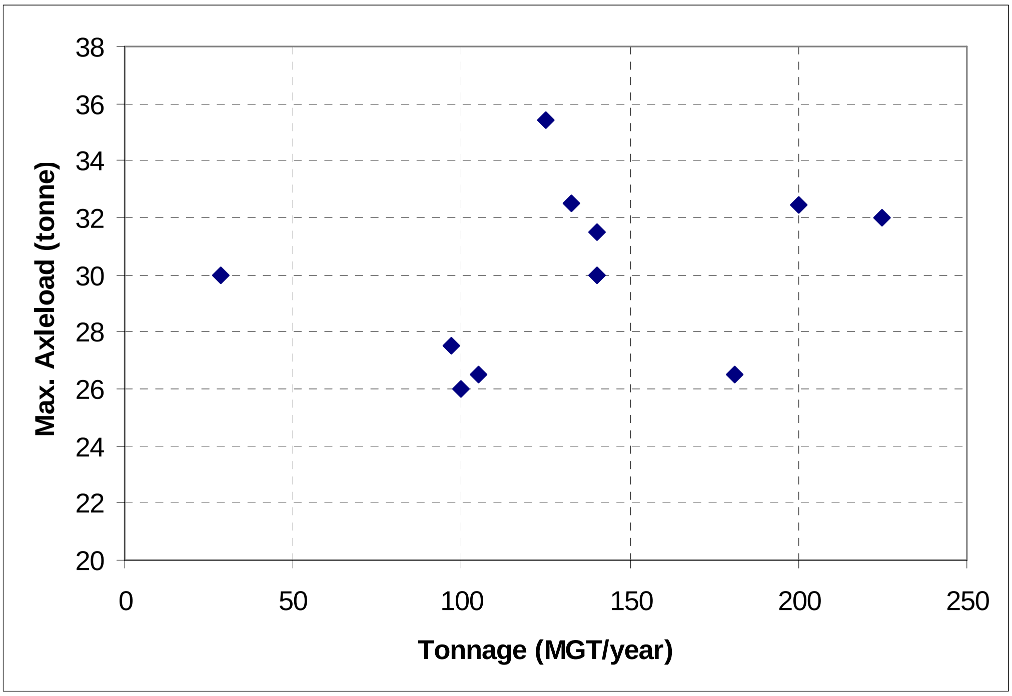

Figure 5: Variation of Tonnage with Maximum Axle load

QR's axle loads of 26.5 tonne are among the lowest of the railways that responded to the questionnaire. The annual gross tonnage of 181 MGT on the Goonyella system is achieved with an axle load of only 26.5 tonne. In contrast, several railways with axle loads of 30 tonne or more transport less than 150 MGT/year. This implies a greater number of wagon journeys per year on the Goonyella system than on many other railways.

2.8 Figure 6 shows the correlation between maximum axle load and rail section used on the railways that provided this data.

Figure 6 shows there is a clear trend of increasing rail section with increasing axle load. QR's use of 60 kg/m rail for 26.5 tonne axle load is consistent with this trend. Figure 6 includes a data point for the Newlands system at 20 tonne axle load and 53 kg/m rail. This usage is also consistent with the general trend.

2.9 Most railways stated that they plan to replace rail at end of its service life with rail having a heavier section. QR is following the same approach and has already replaced most of its 47 and 53 kg/m rail. These sections now only exist in sidings and minor branch lines on the Goonyella and Blackwater systems.

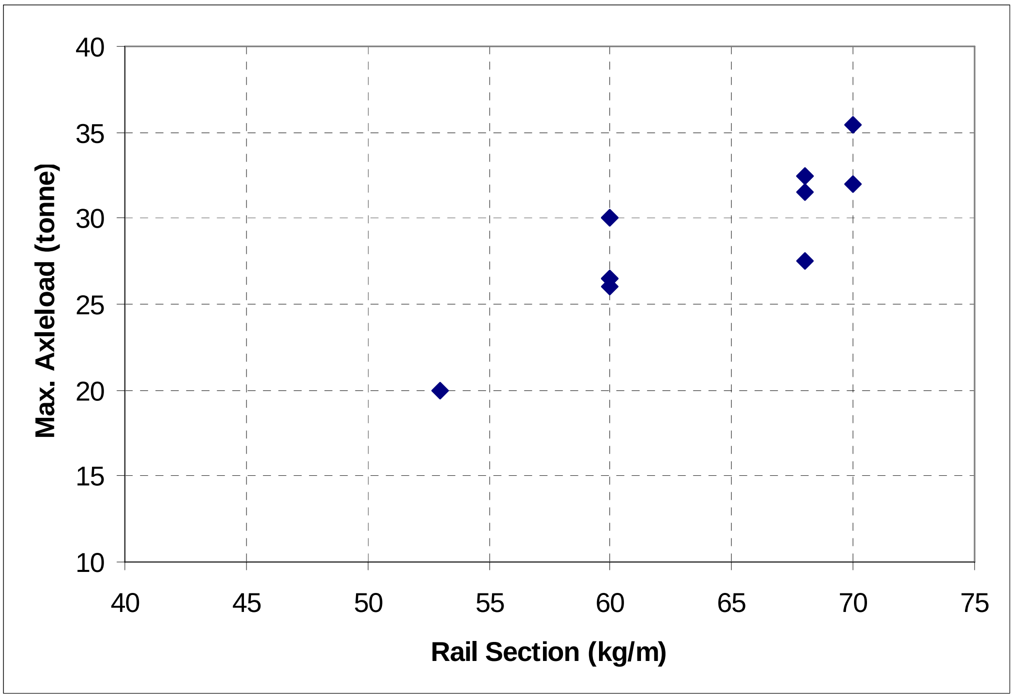

Figure 6: Relationship between Maximum Axle load and Rail Section

Use of a heavier rail profile increases the fatigue resistance and provides more material for wear, thereby increasing the service life of the rail for a given axle load.

Rail Joints

2.10 All the railways that responded to the questionnaire, including the QR Coal Network, use continuously welded rails. This reflects best practice for heavy haul railways. Jointed rails are not suitable for heavy haul railways. High axle loads and tonnages cause large numbers of rail joint failures and track geometry defects at the rail joints.

Sleeper Type and Spacing

2.11 Figure 7 shows how sleeper spacing varies with axle load on the railways that provided this information. It also indicates the type of sleeper used in each case.

Figure 7 shows that, for a given axle load, sleeper spacing for concrete sleepers is wider than that for timber sleepers. QR is unusual in its use of concrete sleepers for relatively low axle loads. Only one other responding railway does the same. Several railways operate with much higher axle loads than QR on timber sleepers. The wide sleeper spacing on QR is consistent with the use of concrete sleepers and relatively low axle loads.

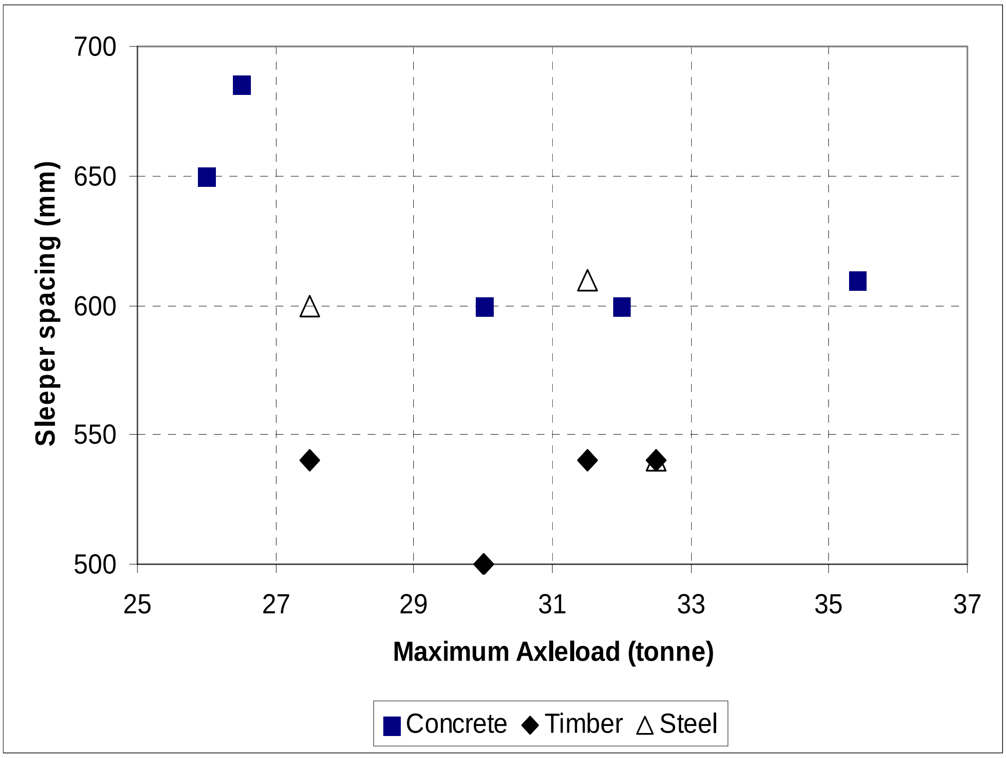

Figure 7: Variation of Sleeper Spacing with Maximum Axle load

2.12 Sleeper spacing in the QR network is defined to accepted QR and Australian railway standards. Cost decisions have to be made at the design stage in relation to the capital cost involved in the number of sleepers versus the predicted capacity requirements of the system. Much of the coal network was designed and constructed prior to the significant increase in international coal demand and subsequent increase in capacity requirements on the system.

2.13 Another important reason to keep an existing standard is the existing tamping machine specifications and methodologies. To change the sleeper spacing on parts of the network could be time consuming and expensive in relation to tamping machine modifications or capital investment on new machines.

Traffic Split

2.14 Figure 8 shows the percentage of freight traffic on all the railways that provided this data. It also shows the principal type of freight commodity that is transported.

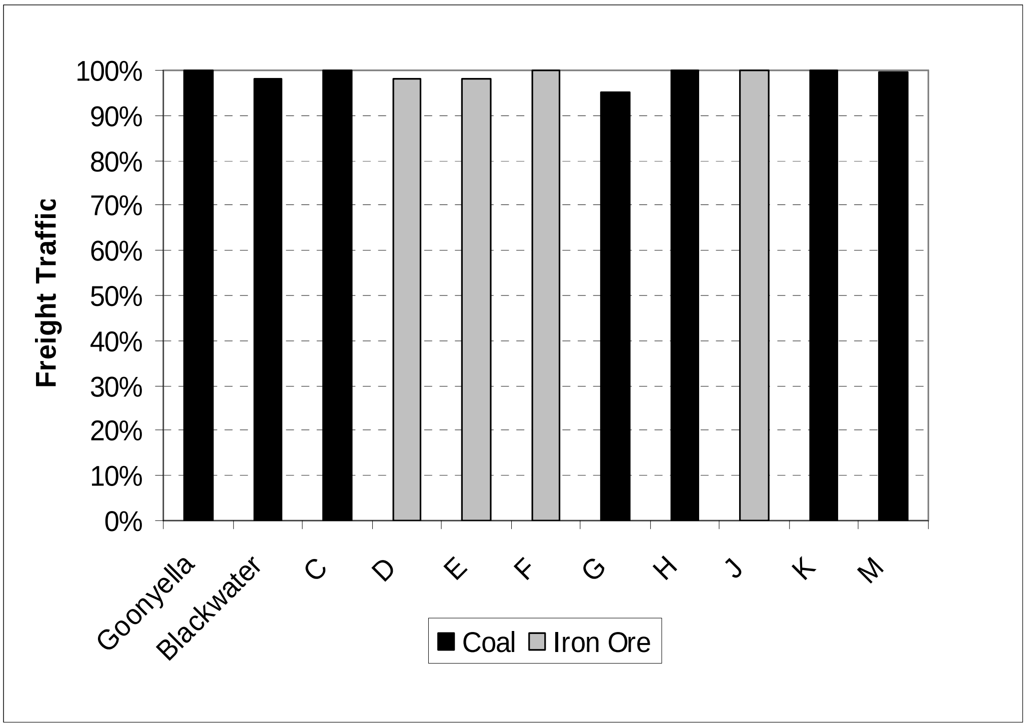

Figure 8: Percentage of Freight Traffic on Railways

Figure 8 shows that all the participating railroads are almost entirely for bulk freight traffic. Some carry a few passenger trains.

2.15 The inclusion of passenger trains on freight lines can create significant additional demands on the system in terms of track geometry (for a smooth passenger ride), rail profile requirements, speed and operational safety. Higher standards are usually required which are not normally significant on a freight only line, where axle load capacity is generally the critical factor. The standard required for these lines is often determined by social demands. Safety needs and the requirements for a 'smooth' ride subsequently increase the maintenance costs of a line that is battered by heavy traffic which a passenger only line does not experience. Hence the combination of the requirements of high standards and heavy use create increased maintenance requirements and subsequent costs.

Turnout Density

2.16 The number of turnouts per kilometre of track has a large influence on the maintenance budget.

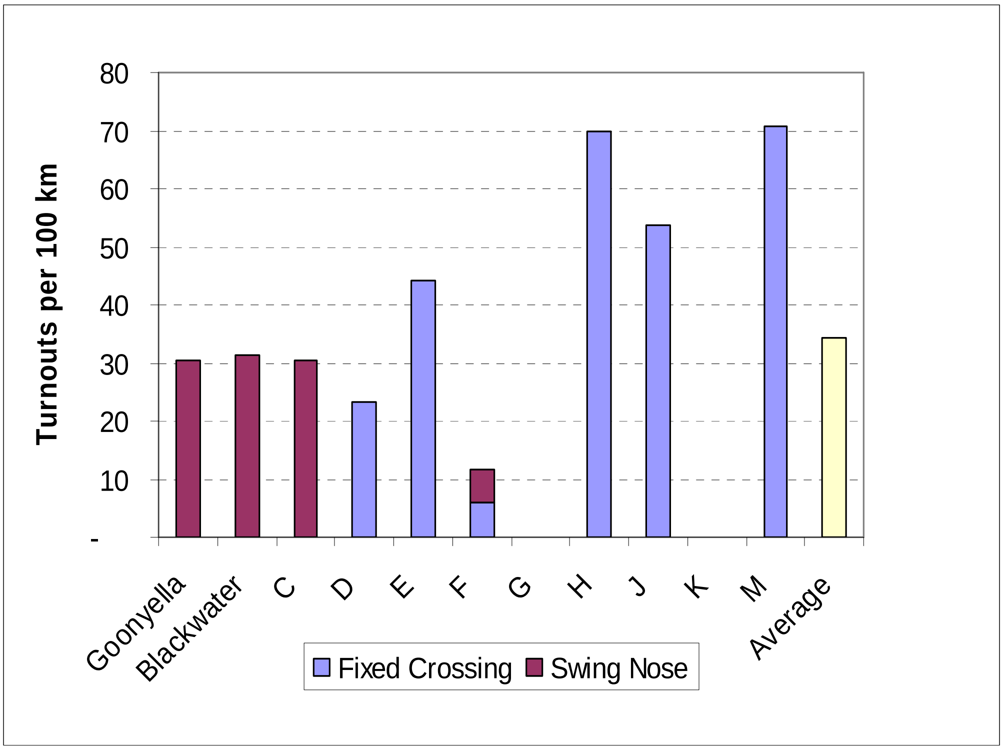

Figure 9: Turnout Densities on Participating Railways

Figure 9 shows the density of turnouts on QR's Goonyella and Blackwater systems is slightly lower than the average of the railways that responded to the questionnaire. QR uses a swing nose crossing as its standard. This type of crossing has significantly lower maintenance costs compared to a fixed crossing. Thus QR's turnout maintenance costs are expected to be lower than other railways that have a higher density and use fixed crossings.

Maintenance

Inspection Regime

2.17 Most of the railways who responded to the questionnaire gave information about their track geometry and ultrasonic testing intervals. The interval between track geometry measurements, conducted by a track recording car, range from three to six months. Figure 10 shows these intervals expressed as gross tonnes of traffic. Railways G and K did not provide this information.

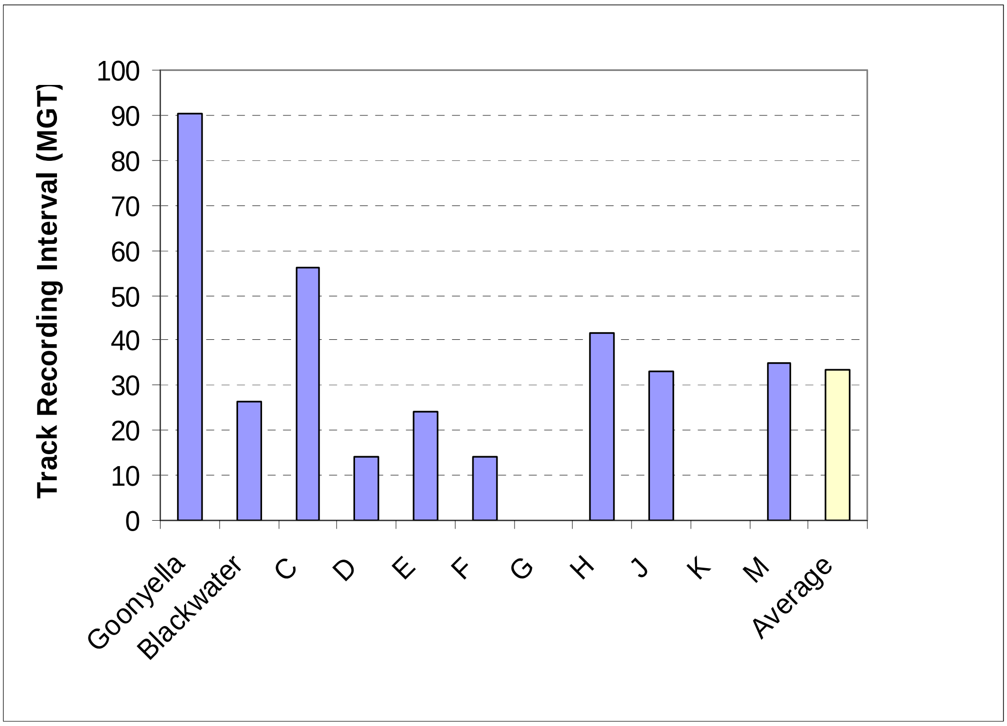

Figure 10: Track Geometry Recording Intervals

Figure 10 shows that the track geometry recording interval cycle on the Goonyella system is more than twice the average over all railways that responded to the questionnaire. QR supplements its track geometry recordings with frequent inspections from hi-rail vehicles. If track access restrictions reduce the frequency of these inspections in future then consideration should be given to increasing the track geometry recording frequency.

2.18 QR plans its tamping using the regular measurements made by its track recording car. This is common practice in freight and passenger railways. The process could be improved by making it easier to overlay several recent track recordings in order to allow deterioration trends to be determined.

Ultrasonic testing using hi-rail or train-borne equipment is performed by all the railways that responded to the questionnaire. The testing interval varies between one and six months. Figure 11 shows the ultrasonic testing intervals expressed in gross tonnes of traffic.

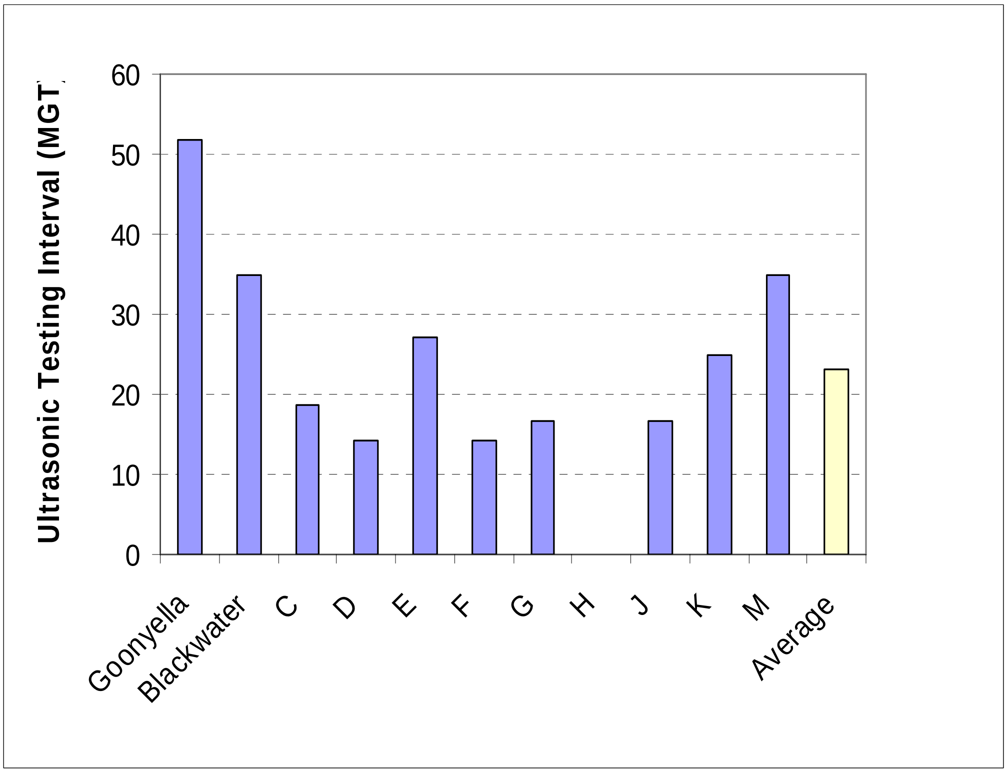

Figure 11: Ultrasonic Testing Intervals

Figure 11 shows that QR's ultrasonic testing interval is longer than the average for the railways that provided this information. The ultrasonic testing interval on the Goonyella system is twice as long as the average. The choice of ultrasonic testing interval depends on the type of rail, the loading conditions, the method of rail grinding and the incidence of defects. An inappropriate choice results in a high rail failure rate.

Rail Defects and Failures

2.19 Figure 12 shows the Mean Time Between Defects (MTBD) for the railways that provided this data. MTBD is expressed as the average gross tonnage of traffic to cause a critical defect in one kilometre of track.

Figure 12 shows that the MTBD on the Blackwater system is close to the average for the railways that provided this information. The MTBD on the Goonyella system is significantly longer than the average. It can be concluded that the longer than average ultrasonic testing intervals used by QR are not resulting in a higher than average rail defect rate, a fact which indicates that QR are looking after their asset effectively.

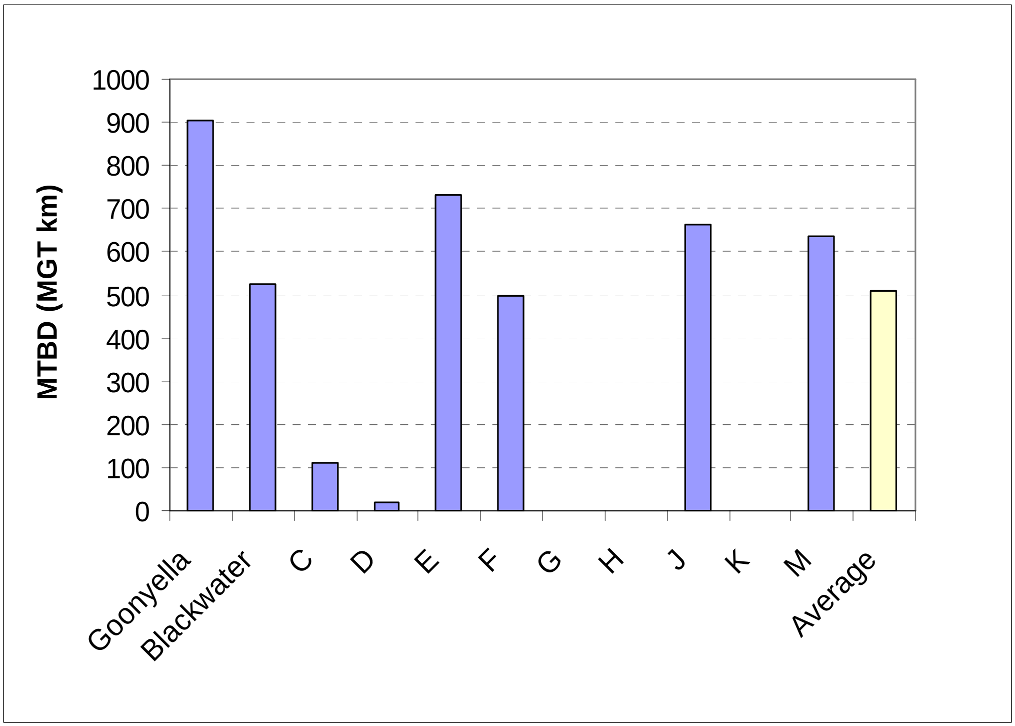

Figure 12: Mean Time between Rail Defects

2.20 Long intervals between ultrasonic testing can result in a high rate of rail failures occurring before detection. Figure 13 shows the Mean Time Between Failures (MTBF) of rails on the railways that provided this information. MTBF is expressed as the average gross tonnage between broken rails in one kilometre of track.

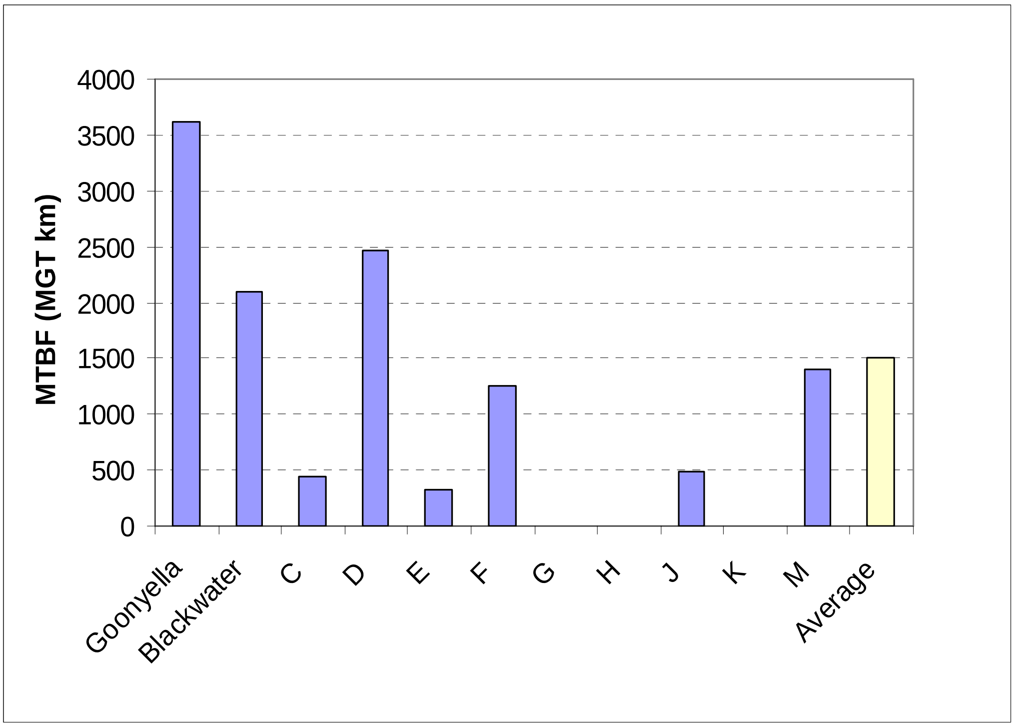

Figure 13: Mean Time Between Rail Failures

Figure 13 shows that the MTBF for rails on QR is longer than the average for the railways that provided this information. This means that the rail failure rate on QR is significantly lower than on most of the other railways. It is further evidence that the ultrasonic testing interval used by QR is appropriate for its track type and traffic conditions.

Rail Grinding Cycle

2.21 Most of the railways that responded to the questionnaire provided information on the rail grinding intervals they use. This information was provided for straight track and curves. Figures 14 and 15 illustrate the ranges of grinding intervals on straight track and curves respectively.

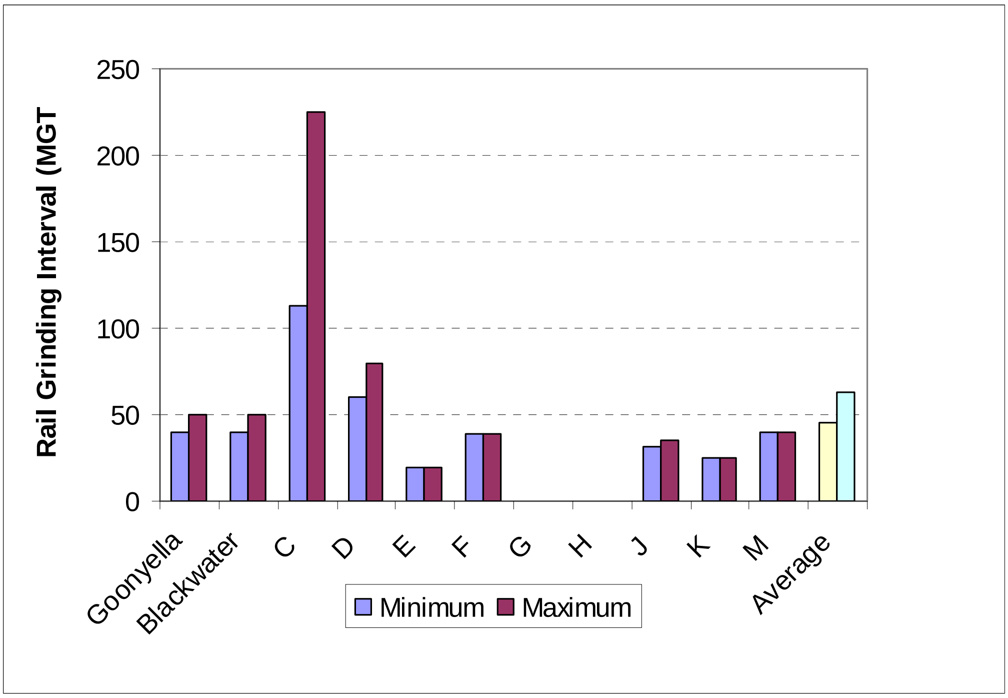

Figure 14: Rail Grinding Intervals on Straight Track

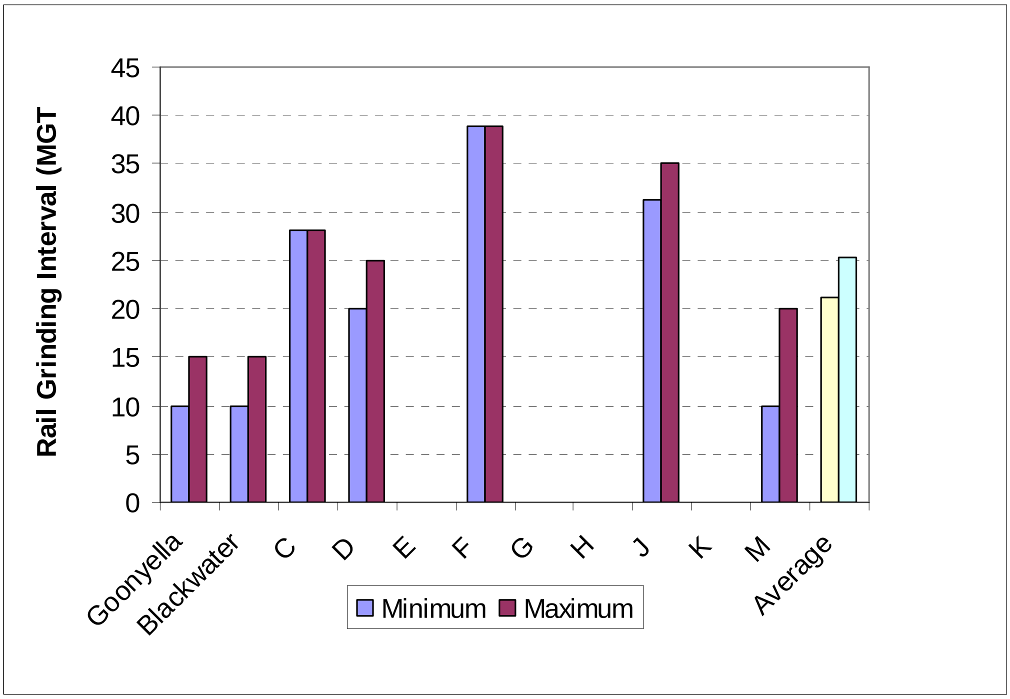

Figure 15: Rail Grinding Intervals on Curves

Figure 14 shows that the grinding interval used by QR on straight track is close to the average for all railways that provided this information. Figure 15 shows that QR grinds its rail on curves almost twice as frequently as the average. One factor that influences the choice of grinding interval is the hardness of the rail.

2.22 Figure 16 shows the range of rail hardness used by the various railways that responded to this question. In general, a different hardness is used for rail in straight track, in the high rail and in the low rail on curves.

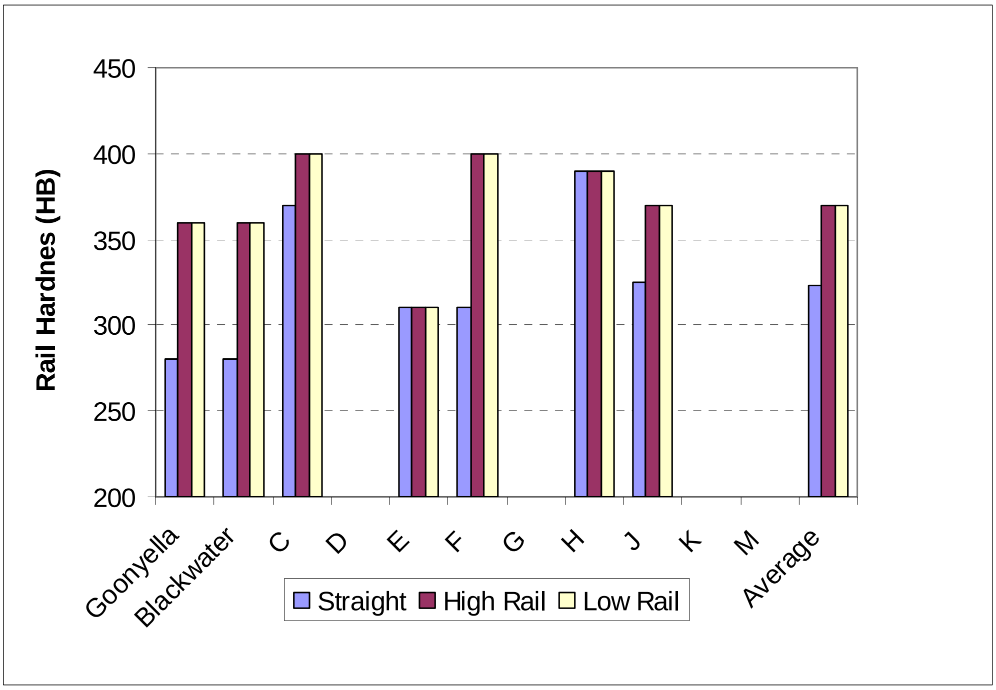

Figure 16: Rail Hardness

QR is unusual in its use of standard rail (280 HB) in straight track. The hardness of rail in curves ranges from 310 to 400 HB over all the participating railways. QR uses premium rail with a hardness of 360 HB in its curves, which is in the middle of the range used by other railways.

2.23 Railways strive to identify an optimum rail grinding cycle in which rolling contact fatigue is controlled with minimum metal removal. This is particularly important for railways whose rail renewal is driven by rail surface condition. Several of the railways that responded to the questionnaire gave this as the principal factor that determines rail life.

Figure 17 shows the rail life for straight track in gross tonnes of traffic for railways that provided this information. Figure 18 shows the same information for curved track.

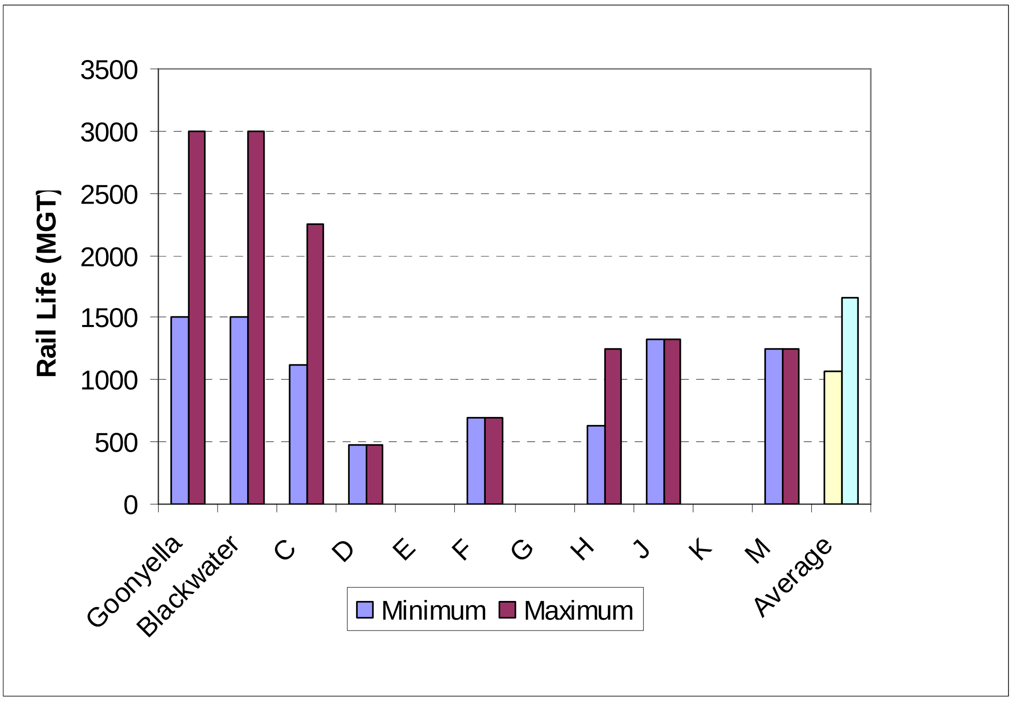

Figure 17: Rail Lives on Straight Track

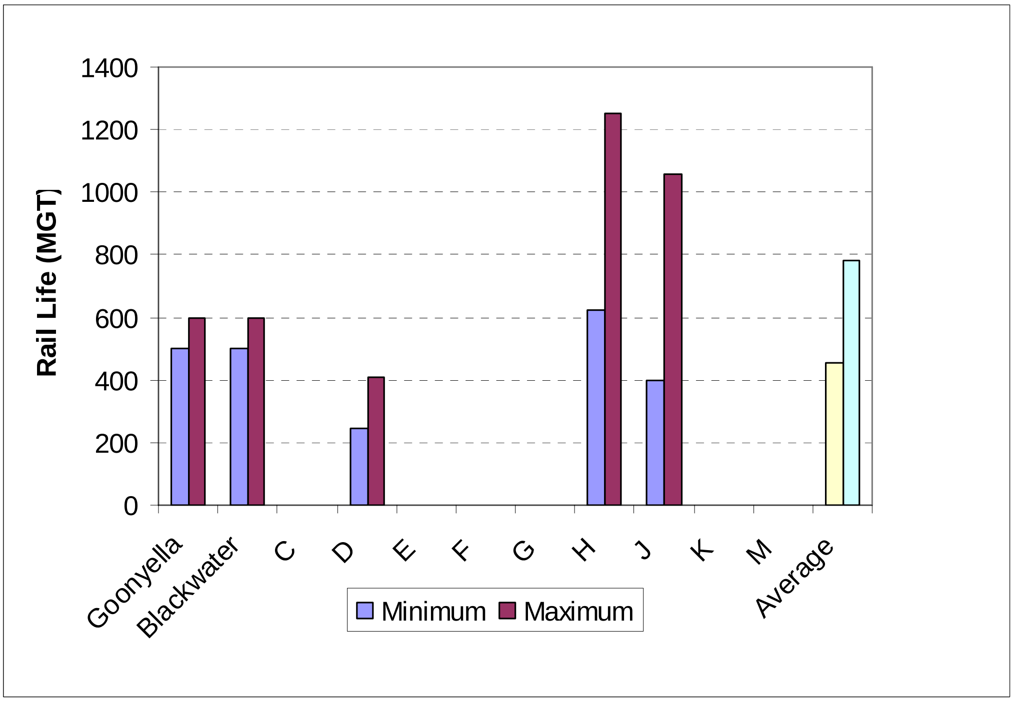

Figure 18: Rail Lives on Curved Track

Figure 17 shows that QR is achieving longer rail lives in straight track when compared to all the other railways that provided this information. Figure 18 shows that the life of QR's rail in curved track is close to the average for all railways that provided this information.

2.24 QR has an excellent process in place for monitoring rail wear. The regular measurements of rail wear and the information from monitoring sites on curves enables good decisions to be made on rail renewal requirements. This knowledge has allowed QR to increase the amount of permissible rail wear, thereby extending rail life. It has also allowed the amount of rail renewal required in UT3 to be estimated accurately.

Tamping Interval

2.25 Figure 19 shows the average plain line tamping interval for the railways that provided this information. The average tamping interval is calculated from the length of track tamped each year, the total length of the line and the gross tonnage of traffic. This allows railways that tamp with regular intervals to be compared to those that tamp on an as-required basis.

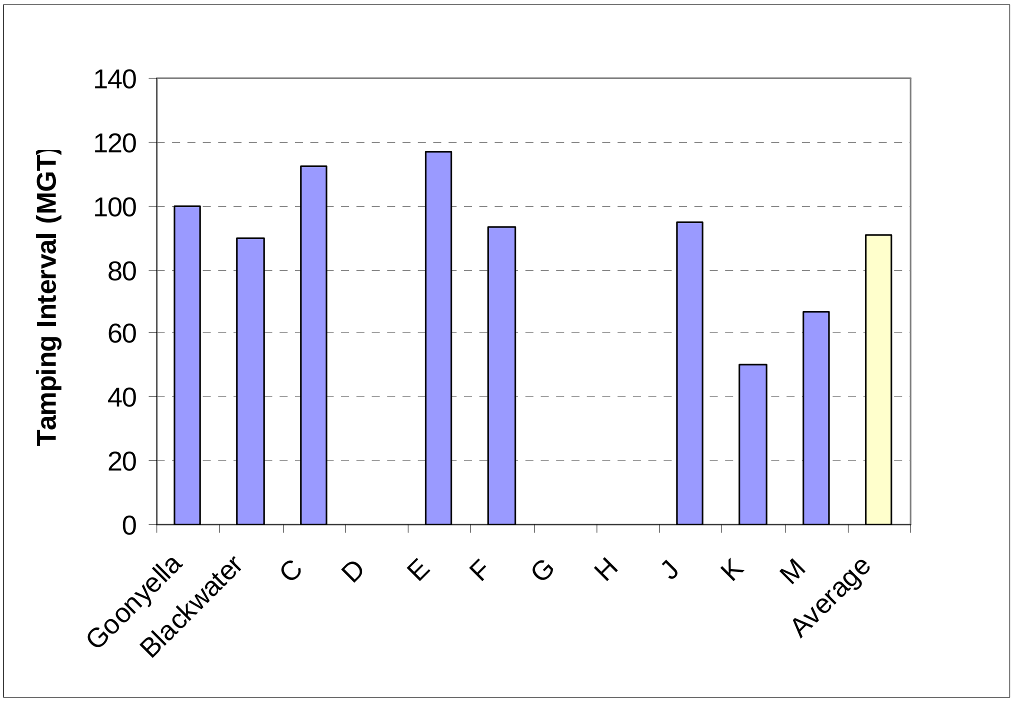

Figure 19: Plain Line Tamping Intervals

Figure 19 shows that the tamping intervals used by QR are close to the average for the railways that provided this information. QR is adding new tamping machines and regulators to its fleet and phasing out some of the older machines. This is a necessary measure to achieve the volume of maintenance tamping that will be required in UT3.

2.26 Some railways tamp their track twice as often as others. It might be assumed that one reason would be they have higher axle loads than the other railways. Figure 20 shows the relationship between maximum axle load and tamping interval.

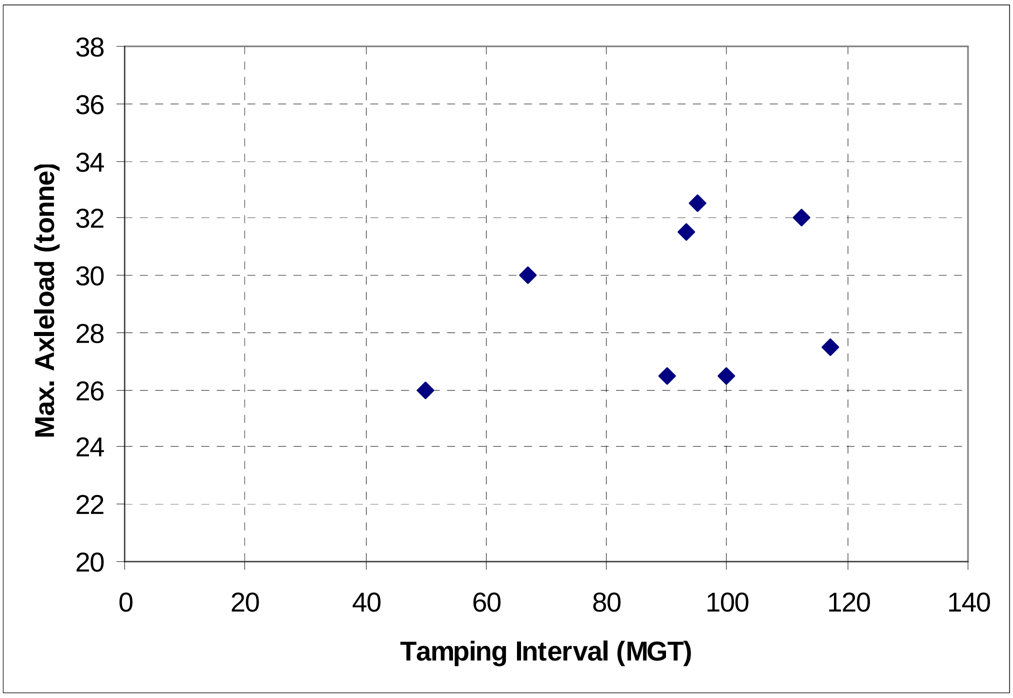

Figure 20: Variation of Tamping Interval with Maximum Axle load

Figure 20 shows the surprising result that tamping interval tends to increase as axle load increases. The reason may be that railways with high axle loads perform more frequent ballast cleaning than others, thereby reducing the need for tamping.

Ballast Cleaning Interval

2.27 Figure 21 shows the relationship between ballast cleaning interval and maximum axle load for the railways that provided this information. This is symptomatic of ballast damage having a non-linear relationship with axle load. If the relationship was linear the ballast cleaning interval in MGT would be independent of axle load.

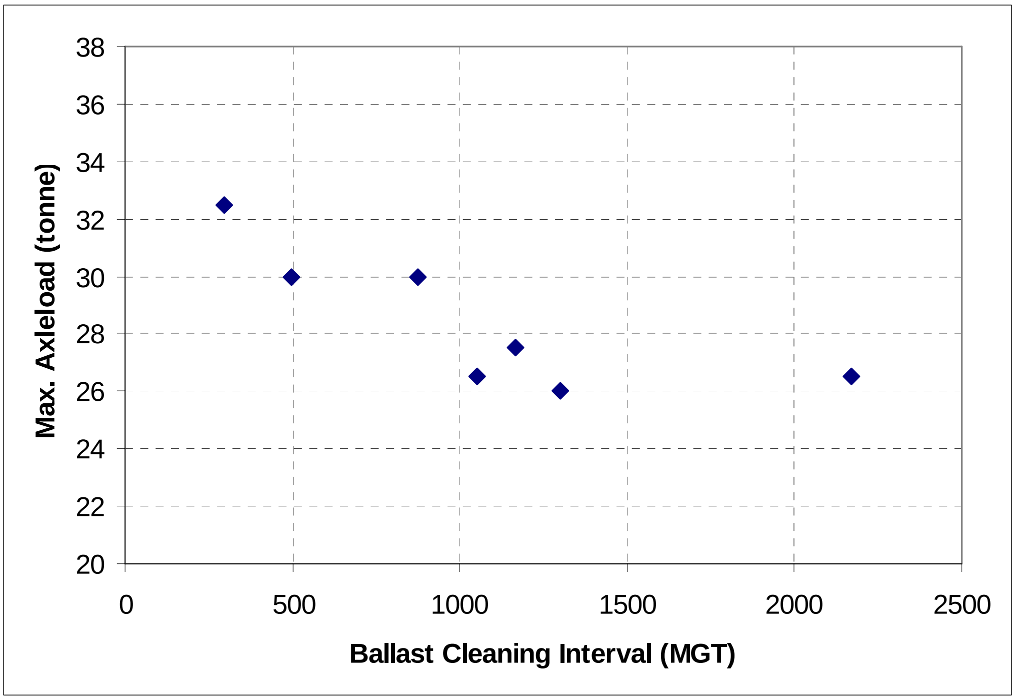

Figure 21: Variation of Ballast Cleaning Interval with Maximum Axle load

Figure 21 shows there is a clear trend of reducing ballast cleaning interval with increasing axle load. The axle load of 26.5 tonne and average ballast cleaning interval of 1050 MGT on the Blackwater system are consistent with this trend. The average ballast cleaning interval of 2200 MGT on the Goonyella system is significantly longer than other railways with similar axle load.

2.28 Although QR has relatively high average ballast cleaning intervals, there are some parts of its network where the intervals are much shorter. Figure 22 shows the minimum ballast cleaning intervals on the railways that provided this information.

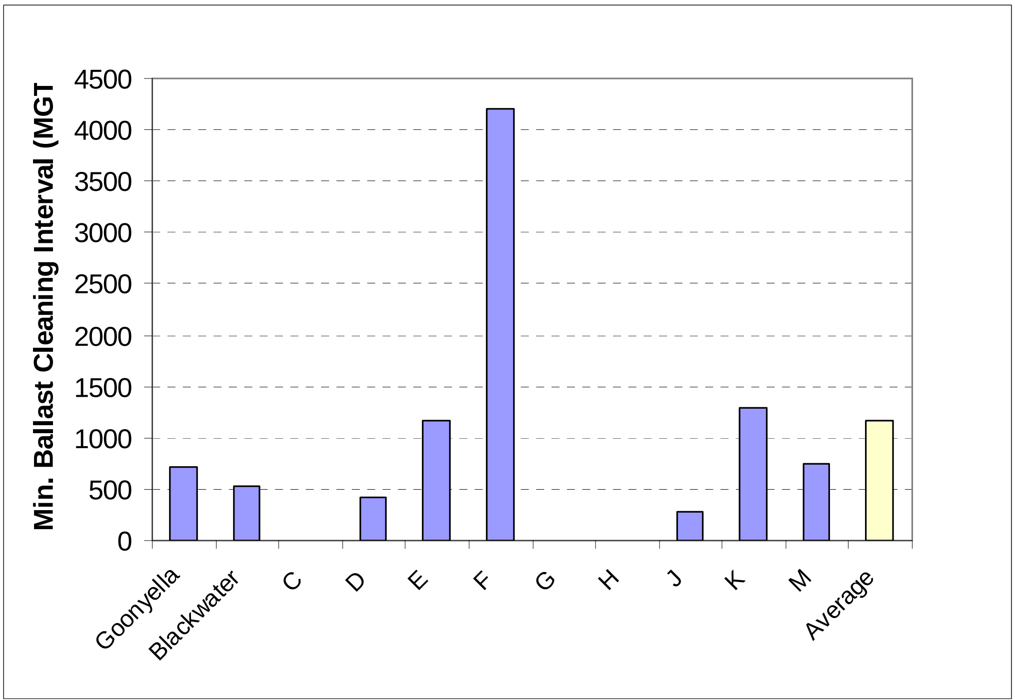

Figure 22: Minimum Ballast Cleaning Intervals

Figure 22 shows that several railways have minimum ballast cleaning intervals similar to those on QR. Short ballast cleaning intervals generally occur at track locations where ballast pollution is severe.

2.29 Figure 23 shows the correlation between fouling and rainfall. The degree of ballast contamination has been found to be related to the critical rainfall in mm/h. In areas of heavy rainfall, as experienced in areas in North West Queensland, this would aggravate the fouling issue.

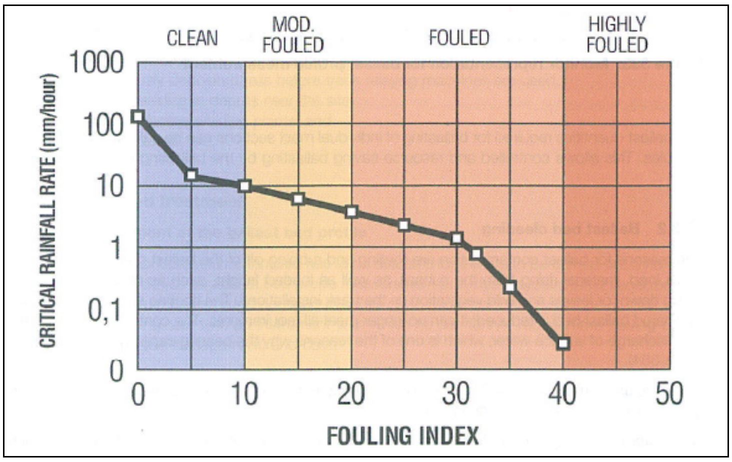

Figure 23: Correlation Fouling and Critical Rainfall2

2.30 Ballast pollution from coal trains on QR's network is a recognised problem. Coal is known to escape from the doors under the wagons, be blown from the top of wagons, fall from overloaded wagons and fall from the bogies where it collects during unloading. Derailments also contribute to this problem. Other railways that haul coal have experienced the same problems. British Rail, for example, reduced coal spillage by adding wind protection to the top of the wagons and by reducing the overloading of wagons.

Iron ore railways also experience ballast pollution from service trains. Some railways are using a spray over the iron ore during loading to avoid spillage in transit. Controlled loading and filters in the wagon drainage holes are also used.

2.31 Ballast cleaning is recognised by railways to be a very expensive activity. It is a slow process that causes significant disruption to service traffic. QR has introduced a process for monitoring ballast pollution to ensure that ballast cleaning decisions are justified. The method involves regular measurements of percent void contamination. Ballast samples are analysed in the laboratory to determine the percent by volume of coal dust that is in the ballast. QR has chosen 30% void contamination as indicator that the ballast needs cleaning.

QR uses ballast cleaning as a preventive measure. Ballast with 30 to 50 percent void contamination may perform reasonably well when it is dry, but after heavy rainfall numerous track geometry faults arise requiring speed restrictions to be imposed. By using a relatively conservative value of percent void contamination to trigger ballast cleaning, QR is avoiding the imposition of speed restrictions and minimizing the disruption to service trains in the rainy seasons.

[2] Track compendium, Bernhard Lichtberger, Eurailpress, 1st edition 2005, p. 522

Railway J claims to clean ballast when the level of pollution in the ballast reaches 60 to 70 % of the available voids. This is significantly different to the value of 30% adopted by QR. By the time the ballast cleaning takes place on the QR network, the percentage of void contamination may have reached 40 to 50%. This is still less than the level used as a guideline by railway J. Unfortunately no justification for this allowance was given, however, reasons may include:

- Conditions are not aggravated by heavy rainfall;
- Lack of maintenance possessions or capacity to conduct maintenance requirements; or
- Standard required is less.

2.32 Other railways monitor ballast pollution by a sieve analysis of ballast samples. The percentage by weight of material passing through a small sieve size (typically 20 mm) is used as an indicator of ballast pollution.

2.33 None of the participating railroads reported using regular ground probing radar measurements to access ballast or formation condition. Ground probing radar has been trialled by North American railroads. One North American railroad is known to be planning to use it to prioritise ballast cleaning and is developing the measurement process and frequency. The use of ground probing radar is being investigated by QR, but no benefits from this technology have been included in the track maintenance requirements for UT3.

Stone-blowing

2.34 None of the participating railroads except QR use mechanized stone-blowing for track geometry maintenance. Stone-blowing was pioneered on British Rail where it is very successful today in treating sections of track that do not respond to tamping. It is used on lines that carry mainly passenger trains. QR is praised for taking the initiative in using stone-blowing to extend ballast life on predominantly freight lines. Some success has already been noted. It is not clear if the potential benefits of stone-blowing have been taken into account when estimating the ballast-cleaning and tamping requirements for UT3.

Sleepers

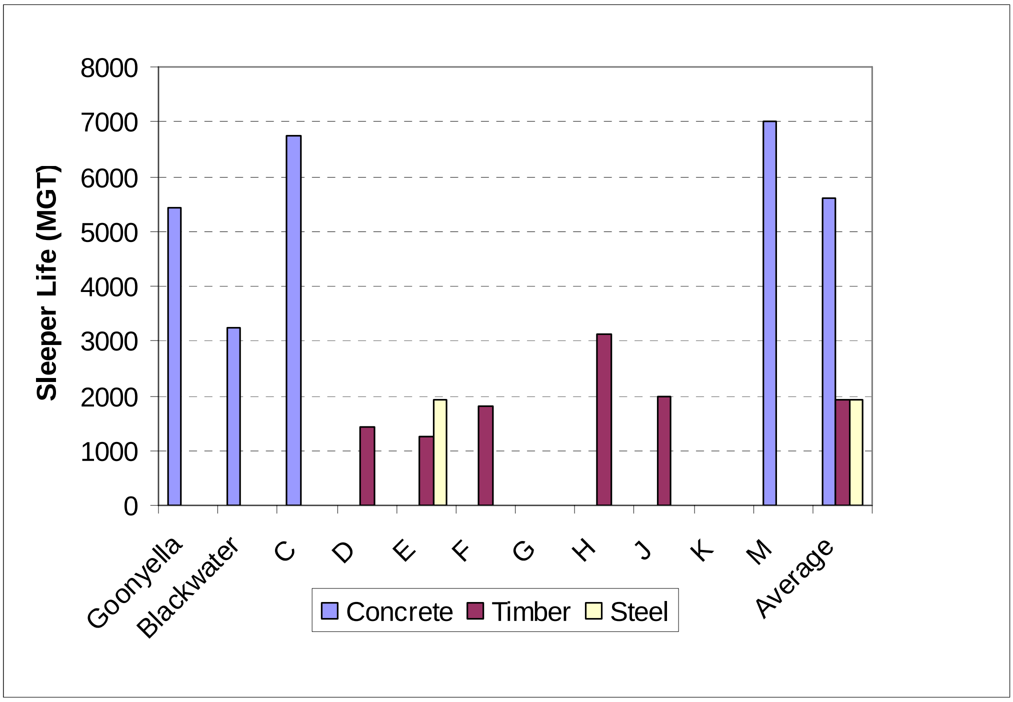

Figure 24: Sleeper Lives and Types

2.35 Figure 24 shows that concrete sleeper lives are generally longer than those for timber and steel sleepers. Railway E, which uses timber and steel sleepers in similar numbers, reports a 50% longer life for steel sleepers.

Figure 24 shows that the concrete sleeper life on the Goonyella system is close to the average for all railways using concrete sleepers. The sleeper life on the Blackwater system is significantly less than the average of other railways using concrete sleepers. The combination of relatively low axle loads and concrete sleepers used by QR is expected to give longer than average sleeper lives. No explanation for the apparently shorter than average life on the Blackwater system is known.

3. SIGNALS AND COMMUNICATIONS

Signals

3.1 Benchmarking a signalling system is difficult because of the variety of configurations and equipment together with the differing life cycles of the various components. An example is relay based interlocking that has been in use for in excess of 30 years and may continue in the future without needing replacement. In comparison is the point machine, which has an average service life of 10 to 15 years. Each asset in a signalling system has its own life cycle. All assets of a signalling system however are generally renewed when a signalling system is replaced even if some assets are relatively new.

To benchmark a signalling system as an asset, the components of the signalling system would need to be identical or of a similar type so as to not distort the results and render the comparison ineffective.

3.2 The QR signalling systems and assets are generally life expired. They are of an age that any benchmarking of these assets may not provide effective comparisons to other railways. The life cycle of the various components benchmarked may be so different that the value of receiving a benchmark on overall costs is not considered to impact on the outcome.

In addition QR was not able to provide sufficient asset management information that would provide any significant benefit to benchmark.

3.3 QR has indicated they are embarking on a replacement signalling system program that may involve technology improvements. This approach will significantly improve the railway assets and depending on the technology chosen, may provide benefits for benchmarking in the future.

Communications

3.4 QR's communications system has been benchmarked against three Australian systems;

- System A (Rail);
- System B (Rail); and
- System C (Road).

The benchmarking has been done by the consultants, based on their knowledge of the relevant systems.

Timing Determines Technology

3.5 The communication requirements for railways have changed over time. With vertically integrated railways, there is an emphasis on providing communication systems for the operations staff, for business applications and for client liaison. A below-rail operator still requires communications for operations activities, primarily for train control, but will have fewer requirements for PABX systems, computer terminals and the like.

3.6 Modern communication systems are based on open standards and (with a few notable exceptions) equipment from different manufacturers can be used interchangeably. Systems can therefore be built and interconnected or extended, without being locked into a particular supplier.

High quality communications equipment, installed and maintained correctly is extremely reliable and is usually designed to create a fault tolerant system with redundancy. Although faults are rare, the remote location of most equipment makes access time consuming so it is normal practice to put in duplicated or redundant systems. The systems are normally designed to automatically bypass faulty equipment.

Extensive fault monitoring and remote configuration capability is built into the equipment. This allows a remotely located control centre to receive alarms and act on them as soon as a failure is identified. The redundant design means that failure of a part of the system does not stop communication: train operations continue.

Continuous Change

3.7 The biggest problem for communication network designers and managers is the rate of change of technology. This affects the networks in three ways:

a) The demand from users for more capacity, speed or flexibility is always increasing, so that a system that was designed with what appeared to be ample spare capacity is soon at the limits of this capacity.

b) The equipment manufacturers respond to these demands and to the continual improvements in device technology by releasing new models of equipment and ceasing manufacture of older equipment. The new models are generally more capable and cheaper than their predecessors but they are definitely different and are not plug-in replacements.

c) Whole generations of technology are going through their life cycles in periods of ten years or less. Most technologies have backwards compatibility but some are incompatible with previous technologies or require gateway devices for interconnection.

The technology used in any particular railway will depend very much on when the equipment was installed and far less on any virtue of that technology compared with the technology of that equipment compared with the technology chosen by another railway. If one were to compare the technology choices of ten railway networks with construction projects active today, they would probably be very similar. Those ten railways would have made completely different choices five years ago and will doubtless make different choices in another five years. Within ten years the systems they have installed today will be obsolete and will probably be being replaced.

3.8 To benchmark maintenance and equipment costs one must therefore compare systems of similar age. There are so many differences in technology, reliability and maintenance requirements that other comparisons are generally not helpful.

Rail System A

3.9 Rail System A is a high traffic bulk heavy haul railway that operates in parallel with passenger and other freight services. System B is a busy line with both passenger and freight traffic. The signalling system for Rail System A on the heavy haul railway uses a combination of relay based and processor controlled systems with network control (both train control and signaller functions) being exercised from one location. The control functions have only recently been centralised as the majority of the signalling was distributed until 2007.

Optical Fibre

3.10 Optical fibre cables were installed along the route some fifteen years ago using multi-mode fibre, with a Microlok signalling system installed over a part of the route3. The vital communications between signalling locations are achieved over the optical fibre cable (where processor control is used) and over copper signalling cables on the remainder of the route. Non-vital signalling communications to the control centre are achieved through the optical fibre cable with automatic switching from the main communication path to a backup connection at the remote end of each communication link. The equipment used on this system is functional but there are some problems at connection locations due to ingress of coal dust over the years.

A mix of serial and IP based technology is now used for the transmission of data from the field to the control centre. The IP based technology has only been installed in the last two years. The majority of the systems continue to use serial data with optical converters.

The backup connections generally use commercial networks. Since the signalling systems have been converted to IP technology for the non-vital links, leased ADSL and BDSL services have been employed. Some connections continue to be on analogue dial-up modems, using both propriety and public communications lines.

[3] Omitted due to confidential material.

Train Radio

3.11 Communication between trains and control is through a special purpose train radio system that uses both conventional mobile radio equipment and satellite telephone communication. The conventional part of the system is owned by the railway and the base stations are largely on trackside sites. (The system is quite similar to the QR systems in this respect). A proprietary protocol is used for call establishment and data transmission. The satellite telephone portion of the system provides a duplicated and redundant means of communication between trains and train control.

This system is used for voice and data communication. The data communication reports the train location from GPS data and any communication equipment faults on the locomotive. Equipment faults at base stations are also reported through the system.

3.12 There is a significant difference in design philosophy between Rail System A and QR. Rail System A has chosen to use a public carrier for the backup part of the train radio system. QR has chosen to build redundancy into the communications links and into the base station equipment. There is a trade-off that has to be made at the design stage between spending capital for redundancy (the QR approach) and paying for redundancy continuously in access and call charges (Rail System A approach).

Rail System A has announced a policy of only using public carrier services for train radio communication. Despite several announcements over the past few years and a substantial investment, implementation is still some years away. The state regulator has required that the existing train radio system be maintained until any alternative system is proved to be no less safe.

PABX

3.13 The PABX facilities on Rail System A are to some extent a left-over from the days of it being an integrated railway organisation. PABX was required until recently as the signal boxes were staffed and there was regular communication with Train Control. It is perhaps debatable whether the PABX systems will be maintained in the longer term. This is because the signals and track maintenance staff are the main group outside train control and most would use their cellular telephones as the first choice for communication.

Maintenance Strategy

3.14 Rail System A has outsourced much of its communications maintenance. Many of the maintainers are ex-staff and most work full time on the system. Some construction activity is performed by the maintenance staff. The majority of the staff are based at the control centre. Alarms are generated by many of the systems and these are monitored at the control centre, with staff dispatched as appropriate to the urgency of the alarms. The duplicated systems for most of the communications permit this delayed response to most faults so travelling time for maintenance staff is minimised.

3.15 It is difficult to compare the maintenance staff levels as Rail System A uses maintenance staff for construction work and system changes. This is also true of QR staff but the practices are so different that comparisons are not useful.

Rail System B

Background

3.16 Rail System B has a rail network that is similar to QR and from a communications view point has very similar requirements. The freight tonnages are much less than those of QR but this does not impact on the communication system.

3.17 The signalling systems used by Rail System B in the corridor that is being compared to the UT3 network is conventional relay interlocking with centralised train control. The centralised control of the network is from a single location.

3.18 There is no optical fibre cable on the corridor and much of the corridor is remote from other development or infrastructure. Rail System B therefore uses its own microwave radio system to connect the interlocking locations. The microwave radio sites have been selected to also provide mobile radio coverage of the line for train radio.

3.19 Diversity on the communication links is achieved by duplication of equipment on the microwave radio system and a ring feed arrangement from the far end of the corridor to the train control centre. The ring feed is achieved by a leased high speed data connection and is through the telecommunication carrier’s optical fibre network.

Train Radio

3.20 Rail System B uses conventional mobile radio equipment for its train radio network. The radio system operates in open channel mode (like QR) so that all trains in an area hear all communication. The on-train equipment is almost standard mobile radio – there is a particular call indication process that uses a feature of one brand and model of mobile radio. (The feature can be provided on any other brand but with additional equipment.)

3.21 The train radio base station equipment is a different brand from that used by QR and appears to have less performance variation. Routine maintenance is much less frequent than on the QR network.

PABX

3.22 This corridor has virtually no maintenance depots or infrastructure, apart from a depot at the far end. Maintenance and operations are primarily based at the control centre, with some staff at the remote depot. Telephones are provided at trackside in some locations and at equipment rooms and are directly connected through the microwave system to the main PABX.

3.23 It could be argued that this would be a sufficient communication arrangement for the below rail operations of QR. There is a difference in approach between the two railways as one provides only essential facilities along the track while the other provides telephone services for commercial operations associated with the railway. Neither approach is necessarily better – it is a matter of policy and cost recovery measures.

Maintenance Strategy

3.24 The maintenance strategy of Rail System B relies more on response to faults and less on routine maintenance than QR. Centralised fault monitoring is employed on Rail System B and this is used effectively.

3.25 The power systems installed on Rail System B have been quite reliable and there have not been any particular problems with batteries. The transmission systems for the backbone microwave link are the same as those used by QR and have had similarly reliable performance.

3.26 Each site on Rail System B is visited at least annually for a physical check and equipment performance is verified during that check. This is a lower frequency of site inspection than is used by QR. The mobile radio base station equipment is a different brand and is around ten years old. The QR equipment is much older.

System C

Background

3.27 System C is not a railway but a road system. The particular portion chosen for comparison is a freeway/tollway that crosses a major city and has many similarities with a rail network. The control of the road is from a central location; there are intersections along the route (in this case at entry and exit ramps) and there are traffic monitoring and information systems along the route.

3.28 The corridor is being upgraded to increase its traffic carrying capacity. This is being achieved by converting breakdown lanes in certain areas to peak hour traffic lanes with electronic lane use management. In addition, the flow of traffic onto the freeway is being controlled by a “ramp metering” system which smooths the flow of vehicles onto the ramps.

3.29 While such a road system might seem quite different from a railway, they have some very similar characteristics. A freeway, like a railway, is almost a one dimensional object, having considerable length but minimal width. There are few branches that are of significance as a part of the freeway – just some junctions. The communication requirements are similar as a high reliability backbone system is needed, with many devices connected to that backbone at intervals. There are controlled intersections at many locations, although these are normally automatic in operation. Operator intervention is required for incidents which may be within the corridor and require direct management; or immediately outside the corridor, requiring communication to the road users about delays.

Optical Fibre

3.30 The backbone communication system for System C is based on optical fibre. To maximise the reliability of the communication system duplicated optical fibres are being installed, with the cables along opposite sides of the road. This minimises the risk of simultaneous mechanical damage to the optical fibre cables. The optical fibre network transmission equipment will be similar to that used by QR. There is a ring feed arrangement from the far ends of the optical fibre to the control centre, with leased circuits for the backup links.

3.31 The optical fibre backbone creates a Wide Area Network (WAN) along the road corridor and all devices are connected with TCP/IP protocols. Remote monitoring is provided for every connected device with extensive remote monitoring facilities. Alarms are generated when there are equipment or system faults.

PABX

3.32 PABX services are not used outside the office buildings. The equivalent to the signal post telephone – the help point or emergency telephone – is directly connected to the public communications network. The most convenient and economical connection method is used for the emergency telephones, with some connected by cable and others through cellular telephones.

Mobile Radio

3.33 There is no specific mobile radio facility in this corridor. Mobile communications are provided through the government radio network, a system operated by a contractor for the whole of government.

Maintenance Strategy

3.34 Maintenance of the corridor has been contracted out to the installation contractor on a five year or greater term. The cost of the maintenance contract is confidential so it cannot be compared with the QR costs. The effectiveness of the maintenance will be measured by reports from the monitoring systems as accurate availability figures for each element of the systems are gathered and recorded by the monitoring systems.

4. POWER

4.1 The age of the power supply assets on the QR systems of Blackwater and Goonyella is, in most cases, measured from the age of respective systems i.e. ~ 2008 – 1987 = ~ 21 - 22 years.

4.2 This implies, assuming that the asset condition is typical of similar power assets of the same age, that for each major class of asset:

- Traction power transformers – should be serviceable for a least a further decade but the units must be carefully monitored. New transformers must be added to the system so that a transformer failure does not result in a significant loss of traction power.

- Auto-transformers – are nearing the end of their serviceable life and a regime of continuous replacement should be considered. The initial auto-transformer design has been found to be deficient (although relatively inexpensive) compared to industry norms. QR has addressed this in their later designs.

- Circuit breakers and switchgear – are technically obsolete and should be replaced with modern designs to ensure an adequate supply of spares. Cannibalization of old switchgear can be undertaken in order to maintain spares for older equipment that remains on the system. Obsolescence not withstanding, the switchgear should be capable of operation for a least another decade.

- Protection relays – are technically obsolete and a regime of continuous replacement should be considered.

- Fault locators - are technically obsolete and a regime of continuous replacement should be considered. It should be noted that many modern protection relays include fault locators, therefore replacing protection relays will probably also resolve any fault locator issue.

- Batteries and battery chargers should be replaced at a frequency of no less than approximately 15 yearly intervals depending on the service conditions they experience (e.g. higher temperatures will result in shorter service life for batteries). If the age of the units is approximately 21 -22 years (which WorleyParsons has been unable to confirm) then all battery systems should be planned to be replaced in the near future.

- Harmonic filters – should be serviceable for a least another decade, with capacitor cans replaced as individual failures occur.

4.3 The Consultant was unable to establish the in-service reliability of the existing assets in quantitative detail due in part to the minimal recording of service statistics since 2004. However, it is expected that this situation will improve as monitoring asset management systems being currently developed are put in place.

In particular it is not known what proportion of assets have been replaced in response to failures. Accordingly the comments given above draw upon the understanding that the Consultant has obtained from QR personnel of the condition of assets. It also takes into account the Consultant's general operational experience of power supply equipment in the rail industry and in the wider power transmission and distribution industries.

4.4 Benchmarking QR against other rail systems with respect to power assets is problematic because most other rail systems in Australia use different electrical arrangements. The QR system, being a more modern AC based network, compares favourably with the earlier systems (e.g. of Sydney and Melbourne) which rely on DC traction supplies. This effectively constrains these systems to operate only as Metro – passenger systems. The coal carrying QR system would not have been achievable without the relatively higher voltage 50/25 kV AC design.

However, it is possible to directly compare QR assets with similar assets used by electricity transmission and distribution companies over a similar time period. Where assets can be directly compared, (e.g. substation transformers and switchgear) the maintenance and asset condition conform to typical expectations for an electrical transmission or distribution company of similar extent and asset age. The one proviso to this observation is that cycling traction loads expose electrical equipment to more onerous operational conditions than the steady loads experienced by electrical utilities. Accordingly, the asset condition of the major equipment within QR is reasonably good.

4.5 The main departure of the railway electrical system compared to an electricity company is the prevalence of auto-transformers on the railway system. On utility systems these units are rare. These are expected to be a significant maintenance cost in the years to come and will require careful maintenance and replacement planning.

5. COSTS AND PROCESSES

Introduction

5.1 The following section analyses the results from the cost and processes questionnaire (Appendix 1). The results from this survey were disappointing with many of the participating respondents on the track and structures questionnaire declining to participate due to commercial sensitivities.

5.2 Due to the paucity of the information it was felt that in most cases averaging the responses and plotting them graphically was inappropriate and added no value to the analysis. Only where it was deemed that value could be added was this approach taken. A detailed discussion on the inference and salient points obtained from the raw data is included as an alternative to graphical representations, where appropriate.

5.3 When comparing expenditure totals one must note that totals will be affected by externalities beyond the control of the railway. These externalities may include increased labour costs or costs for certain safety requirements (i.e. lookout requirements may vary greatly from one railway to another). The comparison of percentages, however, will not be affected by these externalities as all the items will have the same components of these externalities.

Maintenance Costs

Ratio: Track to Structures

5.4 It was anticipated that this question could give an indication of significant differentials in the general split from track, structures, signals and communications and ancillaries.

Figure 25 gives an indication of the split between track and structures, the total percentage allocated for these major items and the remainder. This remainder can be assumed to be made up of signals, communications and ancillary costs. Tonnage per year is also indicated on the graph. This split clearly depends on the density of structures and other cost intensive assets such as turnouts.

No correlation is evident between tonnage and the maintenance ratio. Generally however, the differences between QR and that of other respondents is minimal, with only around 10% indicating that QR's ratio in relation to this general breakdown, follows accepted practice.

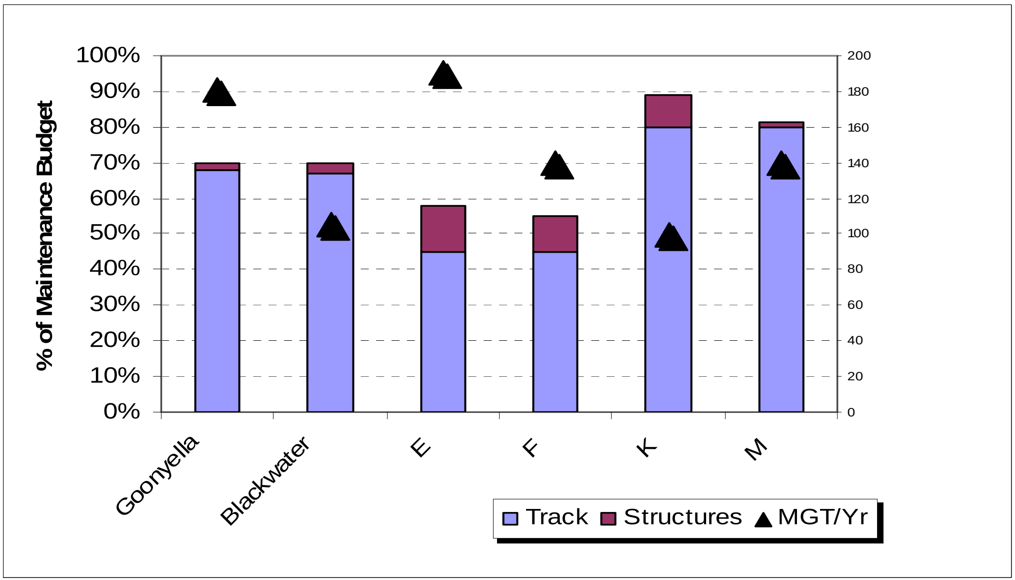

Figure 25: Track & Structures Ratio in Maintenance Budget

Ratio of Bridge Structure Expenditure

5.5 Figure 26 shows the variation of the structures portion of the maintenance budget with the density of bridges, on the railways that provided this information. The density of bridges is defined as the length of track over bridges divided by the total length of the line.

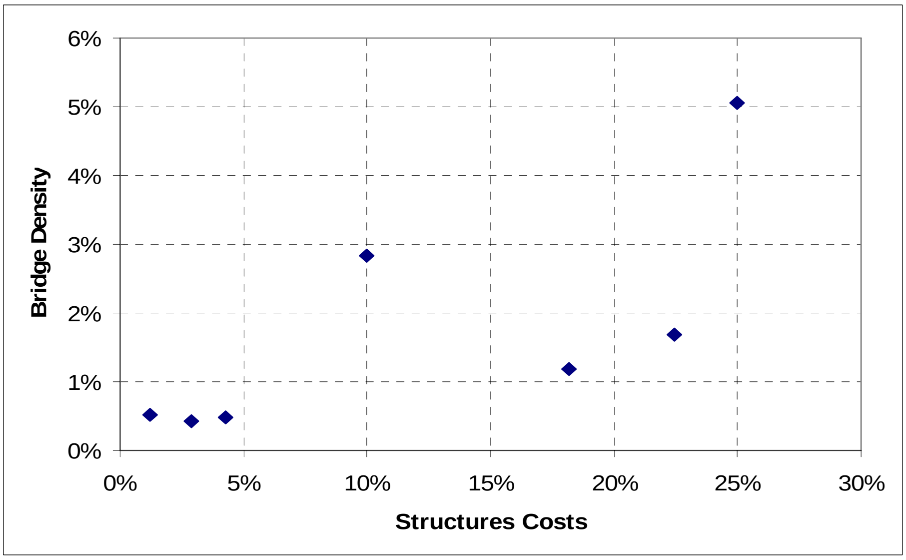

Figure 26: Relationship between Structure Maintenance Budget and Bridge Density

As expected, Figure 26 shows the proportion of the maintenance budget spent on structures tends to increase as the proportion of line on bridges increases. QR has relatively few bridges which is reflected in the relatively small proportion of its maintenance budget spent on structures. This result indicates that QR is probably spending the accepted ratio on items such as routine structural inspections, thus maintaining low rehabilitation costs and extending the whole of life of the structures.

Five Major Expenditure Items

5.6 Respondents were asked to list their five major expenditure items and give the percentages of these items in their total maintenance budget. Although not all respondents gave a percentage they all listed the five major items. These are shown in Table 2.

No	Item & Percentage					
	QR	A	B	C	D	E
1	Ballast Undercutting – 15%	Grinding program – 20.7%	Track maint – 50%	Track maint – 46%	Rail replace	Ballast undercutting – 44%
2	PW Corridor Maint – 8%	Clearing (specific) – 20.5%	Bridge maint – 21%	Railway machine maint– 23%	Turnout replace	Tamping – 6.3%
3	Mechanised Resurfacing – 6%	Immediate maint – 14.7%	Infrastructure maint – 8%	Wagons Maintenance – 10%	Sleeper replace	Rail Grinding – 5.7%
4	Rail Grinding – 6%	Repair after inspection – 12.9%	Rolling stock maint – traction – 4%	Infrastructure maint – 7%	Ballast Cleaning	Turnout steel replacement – 3.0%
5	Preventative Signals M'tce Yards – 4%	Schedule based maint – 9.1%	Wagons maint – 4%	Bridges maint – 4%	Formation rehab.	Drainage and cutting works – 4.3%
	39%	77.9%	87%	90%		63.3%

Table 2: Item & Percentage

From Table 2 we can infer:

- There are vast differences in breakdown and methods of classification between all respondents, making it difficult to make comparisons. Unit costs are viewed as commercially sensitive and have not been provided for the comparative study. It is therefore not possible to make meaningful item by item comparisons; and

- Ballast undercutting and the general item '"track maintenance" are in the highest cost items for all respondents, followed by grinding and tamping

However, if we limit the analysis to the "first" 40% (the total of which comprises QR's five major items) then we can make the following comparisons;

- Railway B has a relatively high grinding and clearance expense, such that this cost is greater than QR's five items combined. This could be due to high external "environmental" or "infrastructure fault" factors inherent in the system or extreme inefficiency in dealing with the problem. Without an efficiency analysis, these causes are speculation. Nevertheless some unusual factor seems to be driving this situation, just as the coal spillage problem does on the QR coal network. Similarly, without an efficiency analysis study (comprising of analysis of actual empirical site data rather than desktop generic comparisons) criticism of the ballast undercutting costs and program on QR can also be considered assumptive;

- Railway E has significant costs in rail, turnout and sleeper replacement – indicating either aged assets or a reactive maintenance policy. QR is bound by regulatory safety requirements and as some of the coal network carries passenger lines, the pressure to maintain these requirements is increased. It would not be considered best practice for QR to take on this approach and hence we note that a great percentage of the primary main cost items are focused on being proactive;

- The only other respondent which noted a high percentage of ballast undercutting is also transporting a high percentage of coal. It is of interest to note that this railway is using tippler wagons which suggests that there may still be significant spillage or there may be inherent problems with formation and ballast conditions.

5.7 These comments, and the differences noted in breakdown and classifications from railway participants show that much in the industry is still based on desktop analysis and generic experience little substantiated by site specific empirical data. This lack of data, on which to build robust formulae is an inherent problem throughout the railway industry internationally. As the demand for robust financial forecasts and assessments by business, financers and engineers increases, the demands for sophisticated data mining techniques becomes an increasingly critical part of any engineering process. In maintenance particularly, it is becoming increasingly evident that good historic specific data records are essential to the assessment of future and current requirements. Without such data, one can only rely on generic desktop analysis, sometimes wholly irrelevant to site conditions. This is not ideal and the responses on Table 2 clearly indicate how site specific conditions can significantly 'blow' the budget item percentages from what is considered the 'norm' or what 'is the expected' (for example "clearing" expense for Railway A).

5.8 Figure 27 shows the 'average' split between maintenance items averaged over the railways that responded to this part of the questionnaire.

It was recognised that these figures would have been more meaningful if compared to the total maintenance budget. However as figures for this total were either not given or were given in a range (i.e. 90% of $10mil- $500mil) it was not possible to include this comparison with any accuracy.

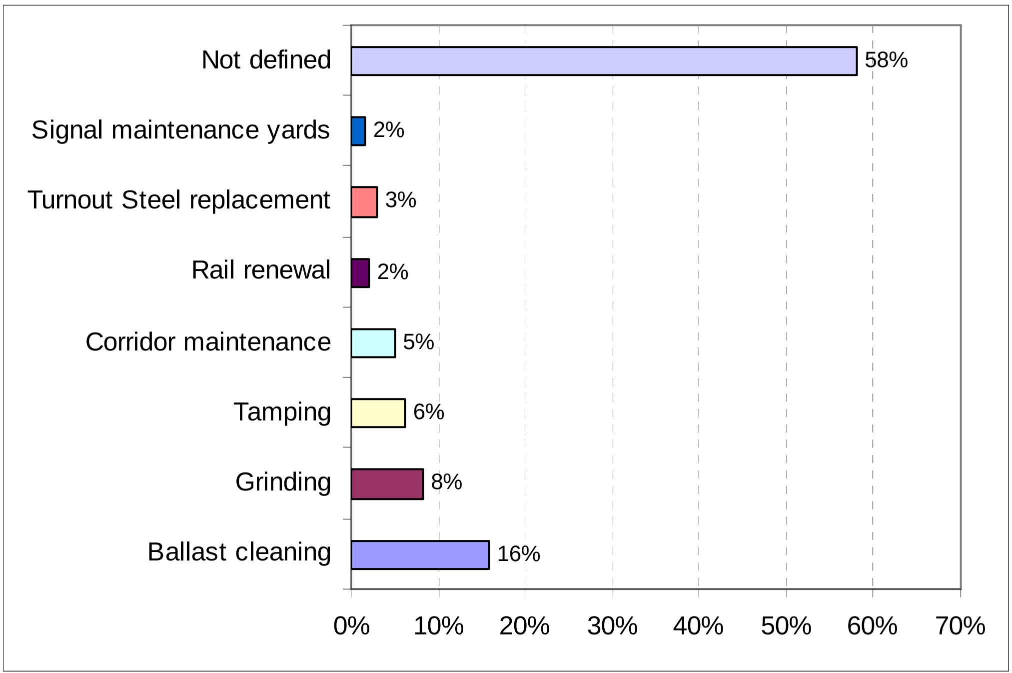

Figure 27: Average Split of Maintenance Costs

From this we can ascertain that in summary ballast undercutting, grinding and tamping are relatively high cost work items for all railways that provided this information. QR figures confirm this trend and indicate that expenditure splits are considered within the normal ranges.

The respondents indicated that ballast undercutting due to spillage is the largest percentage of budget expenditure for railways that transport abrasive and harsh bulk materials such as coal. Unless these conditions prevail (spillage or other adverse external factors), it is expected that all other measures would be under this budget percentage expenditure. The table substantiates this with both heavy bulk railways confirming that ballast undercutting is their highest budget item.

5.9 Grinding is the biggest expense after ballast cleaning or undercutting, and high costs for this activity was recorded by all respondents. Grinding is recognised as being critical in extending the overall track service life. The focus placed on grinding by QR reflects international trends for heavy haul operations and confirms that QR is implementing contemporary theories and methodologies in order to maximise the whole of life of the track.

Annual Expenditure per Main Track Kilometre

5.10 The respondents were asked for their total infrastructure investments per annum including capital investments. They were also asked for a percentage figure for the total maintenance budget from their total annual infrastructure investment. As the information is considered confidential, most of the respondents only gave general comments or alternatively gave large ranges and hence the data received was not generally useful for comparisons.

Total investments per year ranged from AUD6,800 to AUD362,000 per km. The average of the respondents was AUD87,000 per km. Once again the percentage of the maintenance cost of this varied from 75% to 90%, making the data received inconclusive for comparison.

Therefore, to enable some comparison and analysis the following data was obtained from several available resources to compare maintenance costs both nationally and internationally.

It has to be noted that a sample of just one year does not provide sufficient information for a reliable comparison and therefore the results are indicative only.

By comparing European railways with major passenger traffic and then heavy haul railways with major goods traffic, it is clear that there are differences in the modes of transport and their operation and therefore also in their maintenance.

The annual expenditures per main track km for all the European benchmark railways in UIC were taken from an open public internet resource[4]. Letters C to X represent all UIC participants from the last infrastructure benchmark in 2005.

QR data was taken from the actual QR Chapter 2; Purpose, Context & Objectives, Table 6, Forecast. Several 'systems' were analysed for this; "System A" and Rail "System C". Data for these systems was taken from a System A 2007 report, produced by WorleyParsons and available from an open public internet resource[5].

[4] Omitted due to confidential material
[5] Omitted due to confidential material

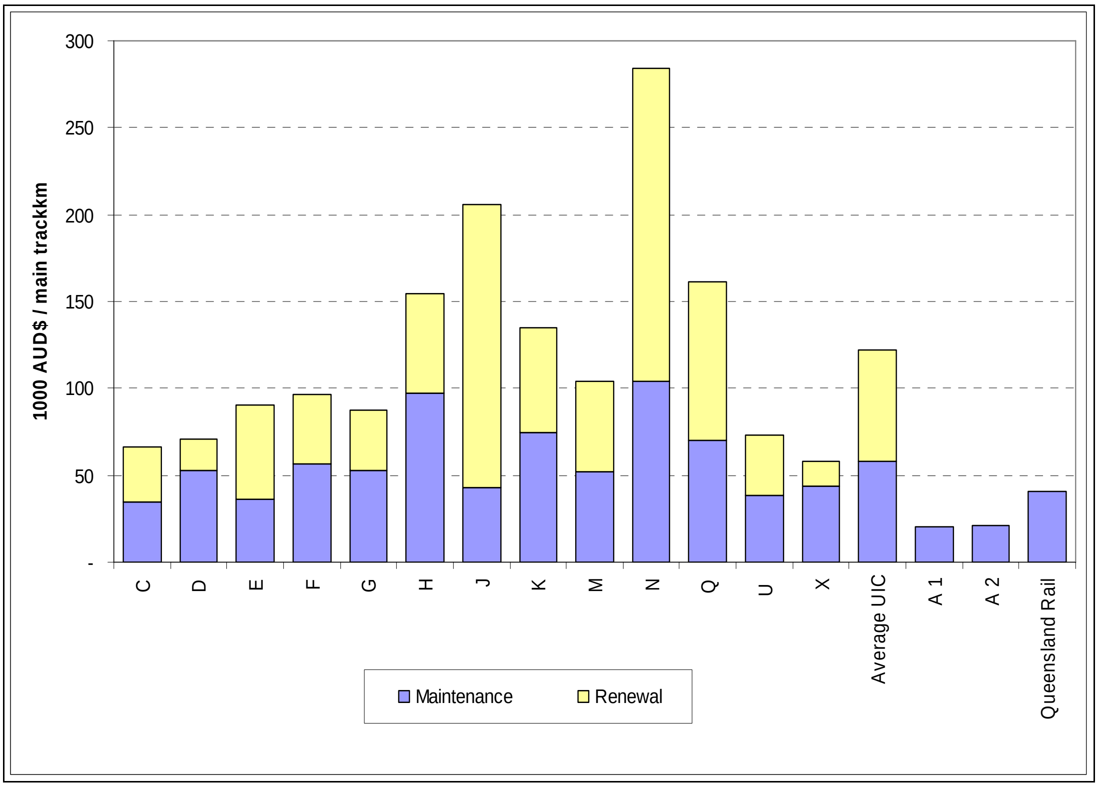

Figure 28: Annual Expenditure per Main Track km

5.11 As can be seen from Figure 28 in comparison with national and international railways, QR's costs remain relatively low.

However, it should be noted that some of the variation may be explained by differences in definition. For example it was noted that many railways classify "ballast undercutting" (as defined by QR) as "ballast renewals" or "ballast cleaning" where existing ballast is cleaned and replaced. Hence without a comprehensive breakdown of each of these totals from each of the participating railways accurate comparison is not possible. Additionally, these figures give no indication of age, environmental conditions or external factors such as labour costs, which may influence the totals in either direction.

Breakdown and Comparison of Cost Components

5.12 When comparing QR's maintenance budget with all the listed railways, it can not be said that QR's maintenance budget is too high. It is still 30% under the average maintenance budget.

Considering the issues caused by extensive spillage on the QR coal network and the subsequent requirement for undercutting or ballast cleaning, the budget per km was found to be comparatively low. A breakdown of QR's ballast cleaning per kilometre of track compared to that of a competitor also indicated that QR costs for this major item are within range.

Possessions Management

Possession Planning

5.13 The responses confirmed that most railways have potential for improvements within the planning processes of their maintenance activities and possessions. QR does appear to offer some flexibility in advanced notice requirements, in comparison with some of the stated cases (i.e. one respondent requiring a minimum of 180 days notice for a planned possession).

In comparison with other railways, QR had a high rate of cancellation of planned possessions (10%, compared with 0.5% for other national railways). A primary reason for this may be the nature of operations on the QR Network, where operations are carried out on a 24/7 basis with no differential between 'off-peak' and peak periods. The cancellation and postponing of planned maintenance possessions may lead to a backlog of maintenance work and subsequent increased requirements in the following year.

A small number of respondents used regular block possessions. Where these were used they tended to be 48 hour blocks and usually about two a year. During that time, key maintenance activities such as ballast cleaning, sleeper replacement and turnout replacements were carried out. This practice does not differ significantly from that currently employed by QR.

Possession Duration and Quantity

5.14 There is a big difference in the minimal time for possession planning between the railway organisations. Figure 29 plots possession planning with maintenance total costs. There is possibly a weak correlation shown between advanced possession planning and reduced costs. It must be noted that in some circumstances, supply chain operations may make advanced possession planning difficult or even impossible.

It should be noted that all respondents have some period of time allocated for advanced possession planning, indicating that it has been found to be best practice to plan these possessions in advance. This would indicate that implementation of work operations without such advanced notice could potentially incur additional costs and is not considered an efficient practice. Short-term possession planning can result in higher maintenance costs.

Strategy and Monitoring

Strategy

5.15 Most railways use mid to long-term strategic planning for their asset maintenance program. Often this conforms to the length of outsourced maintenance contracts. With the implementation of future traffic demand and prediction, most railways tend to target a long-term strategy to allow for traffic increases in a demanding market. Just a minority of railways seem to follow a close-down strategy justified by a short business-case.

Monitoring and KPIs

5.16 All railways use an asset register where they centralise the storage of maintenance information.

The asset strategy is based with just one exception on RAMS.

The main performance indicators were given as:

- Train delays due to infrastructure;
- Hours of freight train delays due to infrastructure;
- Number of delayed freight trains due to infrastructure;
- Number of train disruptions due to infrastructure; and
- Total number of functional disruptions

Just two railways have penalties for non-performance. For these railways one would assume there is a higher pressure to ensure a reliable service.

5.17 The overall conclusion is that the majority of respondents are not recording the required data for detailed computer modelling and maintenance planning, with QR being no exception (data recording is often a casualty of cost reduction pressure, as it is not perceived as having a direct bottom line benefit). Some of the railways stated that there are evaluations and implementation processes for such tools in progress or planned in the near future. It is felt that QR is potentially a leader in this trend with its ongoing development of a GIS based comprehensive track maintenance monitoring and planning system.

Most railways correlate prediction to traffic development and forecast tonnages manually.

Main Focus of Maintenance

5.18 All railways stated that their main focus of maintenance is;

- Safety;
- Availability;
- Costs; or
- An equal balance of the first three factors.

Most railways use maintenance requests from historical data, experience and inspection by local field engineers. The results are entered into a central maintenance plan. With comprehensive simple or modern modelling tools, whole life cycle costs and deterioration data is analysed to assess maintenance needs, allocate priorities and plan mobilisation and budgets.

Asset Management and Overhead Costs

5.19 Depending on overall strategy, tonnage, business case and size of the network, the overhead costs and asset management costs varied from 1-3%. The exception was one organisation which recorded overheads of around 15%. Interestingly this organisation gave the lowest level of maintenance planning operations.

There is a close correlation in overhead costs and asset management, however, without conducting an efficiency analysis of the operations in question it is not possible to say whether further expenditure on overheads and management processes is justified. Currently QR is at the higher end of the average range of responses at 3%, but as there were two other respondents that quoted 3%, this figure is considered to be in the accepted range.

5.20 Only two respondents record track condition or maintenance data directly to a maintenance model. It was not clear whether this recording included both condition monitoring data and maintenance activity details. Just a few railways use modern predictive modelling tools to predict future requirements, infrastructure maintenance and renewal. Models reported were diverse and included rail replacement, track surfacing, risk assessment, switch condition, rail grinding and defect management. Only one respondent recorded using an overall predictive tool however it was not indicated whether this included a GIS component. The overall opinion is that such a tool would maximise the efficiency of planning and potentially decrease wastage of resources, subsequently decreasing costs.

Work Practices

5.21 Most railways with high traffic density and volume use double and extended shifts to work more efficiently during block possessions. Some railways stated that they do not work at night at all due to safety concerns (accident risk becomes much higher at night than during day).

Most railways use a multi-skilled gang structure.

Labour Costs

5.22 This cost varies significantly in countries where labour costs are cheaper and costs for machinery and material are higher. In the current market it is known that labour costs in Australia are generally high and this fact is reflected in Figure 29.

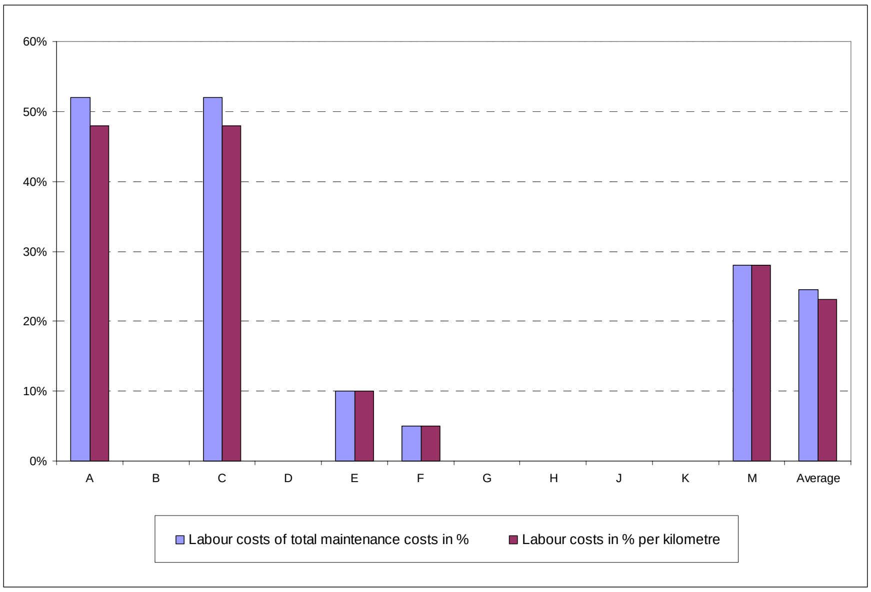

Figure 29: Labour Costs National

All respondents only made use of double and / or extended shifts for emergencies or major closures. All had on-call staff during non-working periods and most rewarded remuneration on these on-call periods at standard rates or declined to give an answer. On-call staff is comprised of personnel of all disciplines (i.e. track, structures and trackside systems).

5.23 Only one railway offered an alternative ‘incentivised profit sharing’ scheme with incentives to reduce cost delays by getting better value for allocated costs during non-working periods. Results from this incentive were not given and the implementation of such schemes can be often complicated through national and state labour requirements and regulations.

6. QUALIFICATION

6.1 In preparing this report WorleyParsons has exercised the degree of skill and care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering design principles.

6.2 WorleyParsons has used all reasonable endeavours to inform itself of the parameters and requirements of the project and has taken all reasonable steps to ensure that the report estimate is as accurate and comprehensive as possible given the information upon which it is based.

6.3 It is not intended that this report represent a final assessment of the feasibility of the project.

6.4 WorleyParsons reserves the right to review and amend all calculations, cost estimates and/or opinions included or referred to in the report if:

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(b) WorleyParsons considers it prudent to revise the report in light of any information which becomes known to it after the date of submission.

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