A NEW HEAVY HAUL RAILWAY FOR HOPE DOWNS-CAN THE EFFICIENCIES BE APPLIED ELSEWHERE?

Eric Englund  BEng CPEng FIEAust MCIT
Bill Singleton  BSc CPEng MIEAust CEng MICE AFPWI MCIT
- Halpern Glick Maunsell

SUMMARY

The Pilbara iron ore railways have undergone continuing development and optimisation to become amongst the most efficient railways in the world. Hope Downs Management Services (HDMS) is proposing a new 370km heavy haul railway to transport 25 million tonnes per annum (Mtpa) from its Hope Downs mine to a port terminal at Port Hedland. This railway, which would be the first complete new railway in the Pilbara in over three decades, needs to build on the existing heavy haul rail experience and also take advantage of being a "greenfields" development.

The paper outlines the planning process by which the permanent way, operations, rolling stock and support facilities are engineered to provide a railway at the leading edge of "World Best Practice". It then outlines aspects of this heavy haul experience that may be applied to mixed railway operations.

INTRODUCTION

From 1995 to 2000, a number of Pre-feasibility Studies for new iron ore export terminals at each of the three Pilbara ports was undertaken, together with connecting railways to the Hope Downs mine, some 60 km north west of Newman. The rail route studies included options for both sharing track with existing railways and for an independent railway. Based on capital and operating cost estimates, plus environmental and project "risk" considerations, HDMS decided to adopt Port Hedland as the preferred port. A bankable Feasibility Study was undertaken in 2001 on a Hope Downs to Port Hedland railway and port facilities south of Finucane Island in Port Hedland. (Ref. 1). HDMS were strongly encouraged in the iron ore market to become the third independent Pilbara producer in place of North Limited, which had been absorbed by Rio Tinto. HDMS have also sought to negotiate sharing and expansion of existing rail infrastructure on a rational and equitable basis.

HOPE DOWNS RAIL ROUTE

This rail route has approximately 352km between a marshalling yard at Boodarie near Port Hedland and the mine loop at Hope Downs. (Figures 1 and 2). The total route length including the port and mine yards is nearly 370km and the track length in a possible ultimate development as in Figure 2 is about 400km. Where appropriate, the proposed railway is located parallel to the BHP Billiton (BHPB) Mt. Newman Railway, principally for environmental reasons. The BHPB railway commenced operation in 1967 and has evolved to be one of the most efficient heavy haul railways in the world. Hope Downs is the first complete new heavy haul Pilbara railway in three decades and lessons from the other systems have been studied and applied.

The railway line has to cross the eastern Hamersley (now called the Hancock) Ranges and the Chichester Ranges. (Figures 1 and 3). In the first 20 km from the mine in the Hancock Ranges, a grade against the loaded train of 0.55% exists and this is the ruling grade in the whole of the railway. From this point, the route is generally down hill, but is partly in narrow valleys with difficult terrain. Route development is ongoing, with the aim of achieving a 0.33% ruling grade for loaded trains, as this will allow longer trains and greater cost-efficiency.

In the Fortescue River valley (313-266km), the route is placed at the foot of the Hancock Ranges, avoiding braided creek systems across the river valley and hence several bridges, as well as environmentally sensitive drainage areas.
Figure 1 – Location Plan
The other major challenge is the Chichester Ranges, with grades up to 0.33% against the loaded train on the south side (255-221 km) of the Ranges. (This compares with shorter but 0.55% grade on the BHPB line here). On the north side of the Chichester Ranges, the BHPB rail route occupies a narrow valley with the least adverse terrain in the area. The Hope Downs route is in more difficult terrain to the west, with the ruling grade of 1.5% against empty trains.

The key feature north of the Chichester Ranges is the Coonarie Creek, Yule, Turner and East Turner River systems. These each require significant bridges. The route is partially parallel to the BHPB line, but deviating to avoid creeks and minimise the impact on natural water flows and hence the number of bridges and culvert works. The bridge locations are away from the BHPB line to obtain a hydraulically favourable crossing and to ensure there are no backwater effects between the bridges on the two rail lines.

From Turner River East to the rail yard near Port Hedland, the route veers west of the existing BHPB railway, to be west of South Hedland and the Bore Creek system, as this is more environmentally sensitive and direct.

An unsealed access road, of similar standard to that on the other Pilbara railways, will be provided along the full length of the rail route.

Figure 2 – Track Layout Diagram (at full production)
3. DESIGN CRITERIA

The design is to embody the best of accepted Pilbara rail practice and to allow interoperability with BHPB. Key parameters therefore include:

- Train consist; initially 220-240 ore wagons as two rakes, say 2.6km length, but allow for a maximum of 320-330 ore wagons as two or three rakes, say 3.6km length. Intermediate locomotives are controlled from the head end using Locotrol III.
- Maximum mainline train speeds; 75kph loaded, 70kph empty, 100kph light engine.
- Initial axle load nominally 35t, but could evolve up to an ultimate 40t maximum.
- Maximum (compensated) grades; 0.33% preferred but 0.55% absolute maximum for loaded trains and 1.5% for empty trains.
- Mainline curve radius; 2000m preferred; 2000m preferred, 1000m preferred minimum, but 600-800m absolute minimum in special situations.
- A reverse in vertical curve, or two changes in the sign of the grade, is to be avoided within the train length.
- Minimum yard curve radii; 500m for loaded trains but 600m in balloon loops and 400m for empty trains.
- Vertical curve radius; nominally 3000m for crests and 6000m for sags, though this may be refined based on train speed.
- The port yard and rotary dumper/indexer would be capable of rakes of about 165 wagons, with the whole train being split and made up at the Boodarie Yard. (See Figure 2).

4. TRACK STANDARDS

Rails will be AS68 kg/m Head Hardened throughout, following cost-benefit assessment of Carbon and Head Hardened rails on tangent track. This decision reflects the needs of higher axle loads combined with the reduced price differential between the two rail types.

Sleepers designed for actual axle loads up 50t, similar to those used by BHPB are specified. A 650mm spacing is assumed, though this will be further reviewed. These sleepers are likely to be manufactured in the Pilbara.
Ballast depth below the sleeper is assumed to be 250mm, but an allowance for an increase to 300mm is conservatively assumed for the Feasibility Study. However, this will be subject to value engineering studies, including the possibility of variable ballast depth depending on track modulus in any area.

Turnouts are proposed to be 1 in 20 with swing nose frogs, both in the mainline and in yards where loaded trains will run. In yard and workshop areas with generally unloaded ore cars and siding stub tracks, 1 in 10 turnouts will be used.

5. DRAINAGE AND BRIDGES

Whilst the Pilbara region is generally arid, it can be subject to localised high intensity cyclonic rainfall events. Drainage design is difficult, where even basic tenets like “rivers always flow in the same direction” cannot necessarily be assumed. There have been many washouts and considerable drainage upgrade works over the last 30 years.

The Hope Downs Project takes advantage of this hard won understanding of the region's hydrology. Bridges and culverts are designed for an average 50 year flood recurrence period. Formations are designed for 0.25m freeboard with a 20 year recurrence ARI design flood.

There are 12 river bridges of 60-240m lengths; ten lower level bridges are composed of 20m spans based on previous designs "optimised" for Pilbara conditions, and two medium level bridges with 30m spans. Two single span bridges, one road over rail and the other rail over rail, have 27.5m spans.

Corrugated steel pipe (CSP) culverts from 0.9m to 3.6m diameter are proposed, though concrete culverts are specified near the coast, due to salt levels. The rail yards at the port and near the coast are designed for the one in 50 year storm surge event as well as rainfall runoff.

6. ROLLING STOCK AND TRAIN SIZE

The selection of locomotives, ore wagons and train size, like other aspects of Pilbara railway design, are the result of rigorous analysis on a system-wide basis, including the use of:

- Train Performance Calculator (TPC) to simulate the performance of an individual train consist on the curves and grades on the given track alignment. This estimates train speeds, travel times and fuel usage. TPC is used to trial different train consists, provide input to the simulation of the overall project and test the track alignment. Figure 4 give a sample of one of the outputs; speed versus distance.

  - Analysis of the train loading systems. The proposed loading system is an overhead bin with train loading under a low constant speed. There are trade-offs between loading rate, bin size, cost and the upstream ore handling system's capacity.

  - Modelling of the unloading system with rotary wagon dumping, wagon indexing system and associated movement of wagon rake to and from the dumper.

  - Detailed simulation modelling from mine to the ship loading including the railway, as a total system with its interactions and variability. This is used to test factors like train sizes, siding locations, timetables, cycle times and tonnage delivered. The model is also used to assess ore handling equipment at the mine and port, stockyard layouts, ship loading operations, shipping patterns, etc.

Locomotives for the Project are assumed to be diesel-electric with AC traction, including:

- GE AC 4400 CW
- GE AC 6000 CW (as used by BHPB)
- EMD SD70/90 MAC

These units have about 33t axle loads and would be equipped with Locotrol EB. There are some modifications to the cab and enhanced cooling systems, based on Pilbara experience, but are otherwise standard heavy haul units. The current preference is a 4400hp unit.

The ore wagons assumed in the Feasibility Study are of stainless steel (3CR12) and designed for rotary dumping. These are compatible with BHPB rolling stock in length and outline, have a tare weight of 21.1t, but have a slightly larger 64m³ volumetric capacity. Even with lower density Marra Mamba iron ores, this gives a payload of up to 126t for lump and 139t for fine ore, ( i.e. 36.8t and 40t axle loads respectively, though lesser axle loads will apply during at least the earlier part of the Project).
There are 275 of the older style steel ore wagon bodies unused but stored at Port Hedland for a number of years. They are in

- Rail testing and track geometry recording, including laser header wear measurement, every 6-8 weeks.
- Rail grinding on curves of 1000m radius or less twice per year, through to tangent track every 2-3 years.
- Rail welding, track surfacing and cleaning of drains and cutting as required.

A permanent maintenance base will be located at the Port, with a base at the mine for part time use. It is envisaged that there will be no intermediate line camps, though use of "flying gangs" is expected.

7. ROLLING STOCK MAINTENANCE

The proposed rolling stock maintenance workshop at Boodarie Yard (Figure 2) would be much smaller than the facilities of this type built 20-30 years ago. Modern locomotives are built with a high degree of modularity. The workshop needs to be capable of modular "change-outs", with service of assemblies, even engines, being done off-site. Heavy body repairs and any other function will also be done off-site where it is economically favourable to do so.

Routine maintenance such as wash downs, bogie and wheel exchange, brake service and testing and light body repairs are allowed for, with a "one spot" and a drop pit. A wheel turning lathe is also assumed.

A "service station" style of trip service facility as to be located near the workshop. (Figure 2.) This is used for daily refueling, lubricant and coolant top-up, cab servicing, waste disposal and windscreen washing.

The maintenance activities are likely to be undertaken by the OEM or other suitable contractor, with HDMS as overall manager.

8. APPLICATION TO OTHER RAILWAYS

10.1 Factors Driving Rail Efficiency

Single commodity railways such as those in the Pilbara have always vigorously pursued efficiencies and minimum unit costs, as this is a direct contributor to overall Project viability and profitability. This objective has been aided by most of the determinants of this productivity being within the control of the Project.

Most other railways operate in a more complex environment of mixed freight operations and possibly passenger trains as well, with trains of differing speed and braking characteristics, size and axle loads. These railways are now under similar pressure to increase efficiency and reduce unit costs, due to factors like privatisation and "vertical separation" with competing train operators. The remainder of this paper will make observations as to how aspects of heavy haul practice, like that described above for Hope Downs, may translate to mixed railway operations.

A key characteristic of Pilbara railways is the systems approach to all aspects of its design and operations. This philosophy applies at the micro level to systems like wheel/rail interaction and maintenance strategies, through to optimising the overall project including the railway and interfaces with the loading and unloading systems. Whilst there may be limits on the direct application of heavy haul practice to mixed railways, this systems approach can and is being increasingly used in mixed railways, even if it is more complex and difficult to apply.

10.2 Application to Route Design

New bulk haul lines, whether or not heavy haul, should be designed to optimise the combination of train power, length, weight and ruling grade in the loaded and empty directions. As well as engineering parameters such as track design criteria, terrain, geotechnology and hydrology, an acceptable alignment needs to cater for environmental and ethnographic features. Train performance calculators (TPC) are used to test alternate train consists on proposed alignments, as part of the alignment design process. In the detailed design stage, modeling of dynamic "in-train" forces may also be used to refine the alignment design where long trains are to be used. However, the above approach may be negated in settled and urban areas, where routes are defined by existing land uses and other historical constraints.

Even in mixed use railways, there will often be a dominant traffic in one direction, such as a bulk export to a port. In this case, the other traffics would benefit from lesser grades in the dominant loaded direction. The lesser traffics may have the power to weight ratio to cope
with grades in the dominant empty direction, especially passenger trains. Alternatively, TPC may aid in finding a quantifiably justified compromise in the grade required by differing trains, to equally benefit the various traffics. A similar compromise may be used where a new line is used in conjunction with existing routes, such as spur lines to mines or the Melbourne to Brisbane AIRE project. (Ref. 2).

10.3 Application to Operations

Train Performance Calculators (TPC), as described in 10.2 above, can also be used in conjunction with simulation models of rail operations to analyse operations, timetables and rolling stock requirements. The TPC is used to obtain sectional running times for various locomotive and wagon combinations for an individual train on the route of interest. This provides input to a simulation model of the multiple interacting trains on the given rail network. Such models usually use Discrete Event Simulation techniques, whereby the model steps through time with the movement and interaction of trains governed by given logic and input data that is an analog of the real system. (Ref. 3 and 4). These models can allow for random variability in running times and delays, plus contingencies like breakdowns and track outages, to realistically represent train operations. The model is used by varying inputs in "what if" fashion to test factors like operating efficiency, turn-around times, tonnes delivered and capacity, and to identify "bottlenecks" in the system. Such models can and should be applied more widely to mixed railway situations, although these are more complex than a single commodity railway. Examples of where such models have been used include:

- Analysis of the superposition of new train types on existing network operations. Timetables, location of new sidings and other track capacity improvements can be tested, eg. the AIRE Project (Ref 2.)
- Analysis supporting the development of track access regimes and the cost of train paths, such as that by the Queensland Completion Authority (Ref. 5).
- Introduction of higher speed passenger trains on predominantly freight tracks, with track improvements and timetabling to the best compromises between the conflicting traffic types, eg. Victorian Fast Passenger Trains, QR Tilt Trains and the new Prospector train in WA.

- Examination of rail access proposals to objectively assess capacity of existing track infrastructure, the most cost effective capacity improvements and the traffic levels at which these are required. This allows the relative benefits and costs to the various proposed traffics to be quantified.

As well as these modeling applications within railways, there is now increasing pressure for transport solutions that yield more efficient operations over the wider transport chain. However, the track, train operations and terminals for loading and unloading may be owned and operated by different parties. The best overall solution may not be optimal for each part of the system and the costs and benefits may not be shared equally. The Pilbara railways have the advantage of a single ownership and have long had models to analyse their whole transport and processing chain so as to pursue lowest cost per tonne. However, simulation modeling provides a means of objectively testing various improvement strategies over both the rail operations and loading/unloading systems in the terminals, and to quantify the separate costs and benefits to each party. In this way, modeling can provide the basis for a "partnering" approach to maximise the overall efficiency in a transport chain.

10.4 Track Structures and Maintenance

The track structure, wheel/rail interface and the associated maintenance, should also be researched and managed as a system. In heavy haul railways like the Pilbara, there has been decades of focus on lowering the life cycle costs of rails and wheels, reducing maintenance costs and possession times, and hence increasing asset life. Comparative studies by UIC Infracost, suggests such railways have 2-4 times lower tonne-km maintenance and renewal costs than typical mixed railways in Western countries (Ref. 6). The underlying key to this performance is an optimal compromise between controlled wear and avoidance of fatigue failures in the rail, given railways are unusual in using this crucial component of their infrastructure plastically.

The procedures developed in heavy haul for high track performance are increasingly well known, but include:

- Premium materials in rail, sleepers and ballast, to an optimal design and constructed and maintained to strict
geometric tolerances. (Head hardened rail is becoming the norm in heavy haul railways even for tangent track, given its proven life cycle benefits and the reduced cost differential with ordinary carbon rail).

- Regular inspection including ultrasonic rail flaw detection and laser head profile measurement. This is supported by techniques to use this data for trend analysis and feedback into the design of the maintenance program that "lets the track tell you what it needs".
- Regular track grinding regime to eliminate defects and maintain a good rail head profile, with a corresponding wheel turning program, based on applied research and track monitoring program.

The above approaches are now being increasingly used to the benefit of mixed railways, though the application and outcomes may differ from heavy haul systems. Apart from direct economic benefit, even passenger trains can attain a better ride from higher quality track. Safety imperatives may also lead to the use of track maintenance regimes like those outlines above, given events like the Hatfield accident.

One interesting example of technology transfer between heavy haul and passenger rail is a partnership between BHP and the MTR in Hong Kong. Using applied research and a structured systems approach developed in the Pilbara, to this rather different setting, has resulted in revised rail grinding cycles, revised wheel profiles, lubrication and changes in rail type and the use of rail pads. Since 1992, this yielded an 85% reduction in rail shelling, a 67% reduction in wheel flange wear and a substantially lower rate of corrugation growth. (Ref. 7.).

10.5 Application to Rolling Stock

There is a strong operating cost incentive to minimise the tare weight of wagons used in heavy haul and bulk commodity railways with payloads in only one direction. Wagons constructed recently for use in the Pilbara have been new designs with stainless steel bodies. This has reduced the tare weight by over 2t, and the operating cost benefits through reduced fuel consumption and maintenance have easily offset the slightly higher initial cost. Where commodities like grain and coal permit, aluminium bodies have also been used. Whilst use of lighter tare wagons is becoming more common in the choice of new wagons, there is yet to be extensive re-evaluation of wagon replacement strategies with the inclusion of operating and environmental cost benefits from such wagons.

Locomotives of the Dash 9 type are now much more efficient and have less maintenance, compared with those built more than about 10 years ago. There is still the attraction of low capital cost with older locomotives, as evidenced by the extensive use of 30-50 year old motive power in Australia. Heavy haul operations can readily show the benefit of recent locomotive technology, with locomotives in the Pilbara being either new units that are less than 10 years old or are older units rebuilt to almost new standard within the last 15 years. For more intensive operations, the choice of motive power and the locomotive replacement strategy needs to be evaluated incorporating the reduced operating costs of current locomotive technology. Moreover, new higher powered units will reduce the locomotive fleet size required by replacing a larger number of lesser powered units. Environmental and greenhouse gas emissions should also be considered in fleet replacement analysis, if locomotive emission standards are not to be eventually imposed by government mandate, as is now happening in the USA with their EPA "Tier 2 Standards".

The most recent evaluation and purchases of locomotives for the Pilbara and other heavy haul railways have favoured AC traction, as this is an application where the advantages of AC are more clearly evident. As the benefits of AC traction are proved over time in heavy haul railways, they may become more common in mixed railways, particularly if the cost differential between AC and DC traction continues to narrow.

EPC brakes are likely to be used initially in heavy haul applications, as the greatest benefits of these brakes is to be obtained with long and heavy trains. Heavy haul may be the primary proving ground for EPC brakes, prior to any more extensive use in mixed railway networks.

There are strong incentives in mixed as well as heavy haul railways, to run longer and heavier trains, so as to enhance the efficiency of the trains themselves and to extend the capacity of the network. However, this means there is a larger train asset at risk in any train
accident, plus potentially greater damage to the permanent way. Asset protection devices like DEDs, HBDs and HWDs, as described in Section 7 above, should therefore be considered for use on higher tonnage mixed railway lines used by larger trains.

CONCLUSIONS

The lessons learned by the Pilbara Railways are directly applicable to new ventures such as Hope Downs, where the evolved experience has been selected in order to supply a new railway designed to be amongst the most cost-efficient system in the world.

Whilst the nature of iron ore rail lines, with a homogeneity of use, optimises cost efficiency, many of the principles can be applied to multi-purpose systems to optimise the combination of route topography, track, motive power, rolling stock, signalling and operations. This is necessary if rail is to provide a competitively economic freight system when compared with competing modes, particularly road transport.

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