INTEGRATED
ECP BRAKING PLUS DISTRIBUTED POWER: FROM BUSINESS CASE TO STRATEGIC CONTEXT

Dr. Dave van der Meulen
Chief Engineer (Systemic Rail Solutions)
Spoornet

1. INTRODUCTION

1.1. *Relation between the present and a previous paper*

This paper is largely but loosely based on one previously presented by the author (Van der Meulen, 2002). Here the author develops the notion of the strategic context of integrated ECP braking plus distributed power, as a concept beyond the business cases already prepared, and explores what the true potential of the new train technology might be.

1.2. *South Africa's heavy haul foundation*

Spoornet's two heavy haul routes, namely the 861km Orex operation, and the 420km COALlink operation, were both commissioned in 1976, using the best technology available at that time. Over the ensuing years, Spoornet and its predecessors implemented several upgrade programs, on both lines, to increase capacity by one or more of the time honoured means, namely increasing axle load, increasing train length, strengthening car- and locomotive fleets, and adding infrastructure. Nevertheless, the fundamental technology remained essentially that of the original generation, and necessarily embodied its well-known train handling and service reliability shortcomings attributable both to relatively slow and non-uniform response, and to high longitudinal forces.

1.3. *Relevant advances in train technology*

In the intervening period, train technology had advanced, more recently through development of electronically controlled pneumatic (ECP) braking, and its logical adjunct, integrated distributed power (DP). The new technologies offered the distinguishing advantage of instantaneous and simultaneous response on all vehicles in a train. An appreciation emerged that ECP braking plus DP, as an integrated package, sharing an intra-train communication system, could eliminate heavy train problems attributable both to steady state and transient non-uniform brake cylinder pressure from wagon to wagon, and to high longitudinal forces.

Spoornet implemented a pilot scheme to evaluate these new technologies. Cortie (2000), Kull (2001), Saarinen (2000), Van der Meulen & Cortie (2000), and Van der Meulen (2001a), have previously described the cable-based PLT10-transceiver-equipped train, evaluation methodology, and detail findings regarding technical- and operational benefits. During the course of that pilot scheme, cable-based intra-train communication emerged as the de facto industry standard.

1.4. *What integrated ECP braking plus distributed power really delivers*

This paper examines the construction of business cases in support of conversion of the abovementioned air-braked operations with head end power, to cable-based integrated ECP braking plus DP, with a view to understanding the strategic leverage that these technologies are able to deliver to heavy haul railways in general.

At time of writing, the Transnet Board had authorized conversion of the entire fleet of Ermelo-Richards Bay COALlink wagons, plus sufficient locomotives, to integrated ECP braking plus DP. A specification is in preparation, with a view to inviting tenders late 2002, and awarding the business in mid 2003. The author further considers the Orex case, and integrates these two to develop an overall strategic perspective.

2. BUSINESS CASE CONSIDERATIONS

2.1. Economics foremost, then strategy

Not all contributions by new technologies are readily expressible in economic- or financial terms. Business cases that include such items must thus necessarily blend quantifiable contributions and strategic considerations. In the present context, the approach was first to establish a positive return from quantifiable benefits, and then to sweeten the decision-making process with additional strategic benefits. The following paragraphs address items that substantiated business cases for integrated ECP braking plus DP in Spoornet.

2.2. Costs of conversion

Unless ECP braking (and possibly also DP over the same intra-train communication system) were applied to a new heavy haul operation, the present early adoption phase of ECP braking technology diffusion would necessarily imply conversion by retrofitting existing air-braked wagon- and locomotive fleets. For the most part, rolling stock will not be new; hence rigorous containment of the costs of conversion, both regarding initial purchase and over the life cycle, is the entrée to constructing a viable business case. The following paragraphs expand this perspective in more detail.

2.3. All-electric ECP braking

Spoornet specified an overlay system for its pilot train, to eliminate the risk of a stoppage for system failure during evaluation. Nonetheless, it shared the industry’s evident preference for all-electric ECP braking, with a pneumatic emergency function, for subsequent conversion of an entire fleet. The preference for fleet conversion does have a bearing on other options. In particular, minimizing investment in feeder service interoperability, to keep costs down, calls for careful thought. In some circumstances, a small proportion of overlay-equipped wagons could facilitate interoperability.

2.4. Wagon equipment configuration

A digital car control device (CCD) has an inherent ability to control multiple wagons electronically rather than pneumatically, which could be attractive from a cost-of-conversion perspective. COALlink has already configured the bulk of its coal wagon fleet, specifically the larger 104-tonne wagons, in rakes of four. The downside risk of multiple wagons controlled by a single CCD is that availability may decline, due to removing multiple wagons from service to repair a fault on one. If reduced life cycle costs indeed outweigh possibly reduced availability, such configuration could become the heavy haul industry standard.

The requirement to handle single wagons at a few unloading sites, that were originally designed to handle wagons of different lengths, or that have tipplers that do not rotate about the coupler centre, as at some sites that support the COALlink operation, is a confounding factor. At such sites, one must uncouple the wagons to pass them through the tippler. This has necessitated a choice of one CCD per wagon, for a small portion of the CCL$^{1/3}$ wagon fleet.

2.5. Integrated air/electric connectors

The pilot scheme experience indicated that reliability of intra-train communication continuity was an issue worth getting right. Two problems emerged. First, passage through rotary tipplers proved to be the weakest link. Recognize however that this issue resulted from cables that were somewhat shorter than the AAR standard. This aspect will be addressed during fleet conversion. Second, cables that had not been re-coupled, at loading sites where trains were cut, caused delays. It is common cause that conventional air brake hose connections reliably survive both environments. The forthcoming Spoornet specification for fleet conversion will therefore entertain cable connectors integrated with glad hands, which piggyback on a connector sub-system of proven reliability.

2.6. Train brake tests

Initial terminal tests serve to prove brake pipe continuity and pressure gradient acceptability, as well as mechanical functioning of the brake valve and brake cylinder on each wagon. The traditional procedure of walking a train is time consuming, and contributes significantly to turnaround time. The alternative procedure of driving by a train is quicker but less rigorous. Moreover, there is still no certainty regarding the effectiveness of brake rigging, from pistons to brake shoes, even after performing a terminal test. Experientially, terminal tests have revealed few defects other than leaks. Therefore, one could arguably extend the interval between visual examinations, without material loss of knowledge regarding the condition of a train. COALlink is therefore investigating alternative ways of proving the condition of a train brake system, using technology.

The continuity assurance and self-diagnostic functionalities of ECP braking establish a sound basis from which to start. Nevertheless, as with conventional air brakes, uncertainty remains as to whether the brakes are functioning effectively after the piston. COALlink has implemented an integrated train condition monitoring system (ITCMS) that, among other, measures the temperature of every wheel as it passes specific locations along the route, and records it in a database. It enables outcome-based assessment of the brake system, all the way to application of braking force to wagon wheels, by enabling comparison of the temperature of each wheel both with that of other wheels on the same train, and with the expected value at each location, i.e. *hot* (brakes applied) or *cold* (brakes released). Hence the procedure proposed for testing ECP-braked trains, namely continuous internal self-diagnosis plus routine external wheel temperature measurement, not only forfeits no knowledge of brake system condition, it rather transcends the traditional regime to test and record functioning of the brake system in its entirety.

The intention is to eventually extend visual examination of complete trains to much longer than the present once at the start of each empty- and loaded trip. COALlink has already modified its process, by omitting the terminal test on ECP-braked trains returning from the harbour at Richards Bay, which yielded a saving of 45-60 minutes.

2.7. Released equipment

A conversion to all-electric ECP braking releases service portions, which may have value in the second hand market and result in a credit in a business case. Spoornet can potentially also use released equipment internally, for converting non-heavy haul operations from vacuum- to air brakes, which would yield a premium over simply selling it on.

2.8. Strategic perspectives

2.8.1. Repositioning for enhanced competitiveness

When train performance variables approach engineering limits in several critical areas simultaneously (typically involving, but not limited to, axle load and train dynamics), operations tend to become too unstable for sustained throughput. The ability to reliably deliver throughput at growing capacity levels is nevertheless vital. By eliminating problems that can sporadically disrupt service, integrated ECP braking plus DP gets to the nub of repositioning a heavy haul railway at a higher level of competitiveness. It is in this area that the greatest significance of integrated ECP braking plus DP has emerged.

2.8.2. People and work

Spoornet, in common with several other railways around the world, is finding that new recruits, in entry grades that lead to train driver, are averse to challenges. In particular, they prefer not to work under what might be regarded as high stress conditions. Planning to adequately recharge the direct release brake system of a long, heavy train for prevailing circumstances, including deviations from routine handling during partial failure and/or infrastructure maintenance, and keeping dynamic coupler forces below failure limits through skilled train handling, are perceived to be high stress activities. Combined with other negative hygiene factors, such as irregular working hours and isolated working conditions, driving trains is relatively less attractive than it once was.

Furthermore, employment equity has resulted in rapid progression from new recruit to heavy train driver in Spoornet. While materially shortening the learning curve can still deliver a train driver who is competent to deal with normal operational conditions, it may deny aspirants the exposure and seasoning that come with extended, grounded, career development. Short development leads, among other, to insensitivity to impending train-handling trouble, such as the onset of a train break under extreme longitudinal loading, and absence of the seat-of-the-pants feel that keeps train slack prepared for the unexpected at all times.

ECP braking shortens stopping distance to the extent that a train driver can almost drive on sight, as with a road vehicle. Its graduated release characteristic and continuous reservoir charging eliminate the stress of planning train handling. Well-designed distributed power renders a heavy train all but unbreakable in most circumstances. These attributes of the new technologies remove major negative hygiene factors, thereby aligning the train driver's job with the people available or designated to do it.

2.9. Application to other settings

The foregoing discussion necessarily rests on experience in Spoornet's heavy haul operations. Although the nature of the benefits is founded on the technology itself, the absolute and relative values of benefits could vary according to the architecture of the system in which they are implemented. Two aspects are particularly relevant. First, an operation that has already implemented distributed power will find no additional benefit from reduced tractive forces, as they affect coupler failure and track damage. Second, diesel traction is less prone to apply abnormally high track forces than electric traction, because each locomotive generates power independently, rather than drawing it from a dynamic network supplying several trains, hence the benefit of reduced track damage will likely not apply when moving from head end power to distributed power.

3. THE COALLINK BUSINESS CASE

3.1. The context

The COALlink integrated ECP braking plus DP pilot scheme demonstrated economic and strategic advantages over a period of one year in service. Spoornet is therefore preparing to retrofit a fleet of approximately 6700 wagons, and nearly 200 locomotives to varying extents, with appropriate equipment. The following paragraphs illustrate some of the technical and economic challenges that had to be overcome, within the obvious constraints of commercially available technology and an acceptable profitability index.

3.2. Feeder services

3.2.1. Diversity implications for ECP braking

COALlink supports complex and diverse feeder services between loading sites, intermediate exchange yards, and the yards at Ermelo and Vryheid where it assembles line haul trains. Upwards of forty mines are involved, located in several coalfields. Conventional air brakes accommodate such operational diversity seamlessly. Although the conversion will result in a dedicated fleet of wagons, interoperability remains a key issue. The following paragraphs describe the major services: One-off deviations, not mentioned here, may exist.

3.2.2. The Mpumalanga Coalfields

Mines in these fields are located to the north west of Ermelo, the farthest being some 160km distant. Predominantly 3kV DC electric mainline locomotives service them. Diesel locomotives service the remainder. They generally have rapid loading facilities, which COALlink supplies with blocks of 100 wagons. Many of them rely on low-speed-equipped locomotives to move trains through the loaders. Either mechanical indexers, or a variety of locomotive types, work the remainder.

3.2.3. The Waterberg Coalfield

This field is serviced with 100-wagon trains, hauled first by diesel locomotives to Thabazimbi, then by AC electric locomotives to Pyramid South, and then by DC electric locomotives to Ermelo, a total distance of 640km. This traffic is relatively low volume, around one train per week.

3.2.4. Yard working at Ermelo

Blocks of 100 loaded wagons from the mines, hauled by DC electric- or diesel locomotives, arrive in the D-Yard. A pair of diesel locomotives then combines two of them and hauls them round a balloon to the loaded 200-wagon train departure A-Yard, where the AC locomotives are attached. In the empty direction, 200-wagon trains arrive from Richards Bay in the B-Yard, hauled by AC locomotives. A pair of diesel locomotives then hauls them round a balloon and places 100 wagons on each of two roads in the empty departure C-Yard, from which they return to the mines once more.

3.2.5. The KwaZulu Natal Coalfields

Mines in these fields are small, and Spoornet typically supplies them with blocks of 50 wagons. This territory, electrified at 3kV DC, extends from Vryheid to exchange yards near the mines, some 150km distant. From these yards, either Spoornet- or mine-owned diesel locomotives place the wagons in mine yards. Thereafter, some mines cut the trains into blocks of around eight wagons for loading, using small industrial locomotives. The process reverses after loading.

3.3. The Ermelo-Vryheid-Richards Bay main line

Feeder trains are combined at Ermelo and Vryheid into 200-wagon trains, for haulage to the harbour at Richards Bay, by either five or six Class 7E1/3, or four Class 11E, 25kV locomotives, currently at the head end of the train. Applying integrated ECP braking plus DP to this core operation will in essence scale up the pilot scheme from one train to all trains. Distributed power will enable the currently incompatible Classes 7E1/3 and 11E to run in the same physical consist, but in two logical consists grouped within a fence.

When it is necessary to work 200-wagon loaded trains over the 1.52% graded original line, during maintenance occupation or service disruption, six manned diesel helper locomotives are added to the train, currently at the rear. At completion of the fleet conversion, distributed power control will control these helper locomotives, to give one driver control over the entire train. If the event is planned, the remote electric locomotives will be placed at mid-train upon departure from Ermelo, and the helper locomotives added at rear where required. If the event is unplanned (i.e. it occurs after departure from Ermelo), and the remote electric locomotives are already at rear, the helper locomotives will be cut in at mid-train.

3.4. Interoperability with feeder services

3.4.1. Traction

In the light of the diversity of locomotive types that support the core operation, that will need to be converted to work ECP-braked trains, it is advantageous to constrain diversity to minimize costs. Furthermore, where the benefits of conversion accrue to the line haul railway operator only, mine operators seem reluctant to bear the cost of converting locomotives. Spoornet has therefore specified transition vehicles, or transition devices, to avoid undue costs for small, one-off, fleets of non-mainstream locomotives. This solution will complement the core fleet of mainline ECP-equipped locomotives to support seamless operation. As specified, transition equipment and distributed power will be mutually exclusive.

The variety of Spoornet's and its customers' traction types may elevate the complexity of conversion. On the one hand, this situation illustrates one of the inherent disadvantages of electric traction, in that the power supply network typically does not cover an entire operation. On the other hand, otherwise comparable, but less diverse, railways ought to be able to build a commensurately more robust business case for ECP braking.

3.4.2. Braking

A few mines cut the trains supplied by Spoornet into smaller blocks (less than ten wagons), to work them through their loading stations by means of light industrial locomotives. The latter are typically equipped with 24V automotive electrical systems: It is not considered viable to equip such locomotives with specially engineered ECP braking equipment, nor to provide a transition wagon or -device for such small cuts of wagons. Spoornet therefore requires the following functionalities. First, car control devices must wake up on application of brake pipe pressure. This will allow wagons to go into sleep mode at such loading sites, to conserve battery charge, and wake up when required to support movement, without the application of cable power. Second, car control devices must provide limited emulation, by which they monitor brake pipe pressure modulation and direct the appropriate pressure to the brake cylinder. This solution will permit air brake equipped light industrial locomotives to move small cuts of wagons at low speed over short distances.

3.5. Fundamental business case content

3.5.1. Generic benefits

Some benefits of integrated ECP braking plus DP are generic, and apply across several content items, as follows:

Integrated ECP braking plus DP enhances train handling fluency. First, the graduated release characteristic and continuous reservoir charging enable a train driver to drive without thought for the state of charge of the system. Second, short stopping distances enable a train driver to drive almost on sight, without regard for difficult stops. Last, bracketing the train between the lead- and remote locomotive consists enables a train driver to control the train more precisely. Over-the-road train performance is thus significantly faster.

The ability to start a train on any up grade means that there is no need to hold trains back while preceding trains clear a section, as in the case of critical signals at which train control officers and train drivers should not stop heavy trains.

Continuous reservoir charging means that there is no delay should a train stop on a steep down grade. Note that asymmetrical up- and down grades, mean that locomotive independent brakes cannot hold a train while recharging the automatic brake: Use of the holding brake incurs a time loss of some thirty to forty minutes per application.

Set-up and testing can be faster with ECP brakes than with conventional air brakes.

Together, these benefits reduce the amount of wagons and locomotives needed to deliver a given throughput tonnage. When packaged and ranked in descending order of percentage of total contribution, they stack up as follows:

3.5.2. Reduce wagon fleet requirements—39%

Integrated ECP braking plus DP accelerates turnaround through more fluent train handling and quicker brake testing. Faster turnaround enables a railway to convey a static volume of traffic with a smaller wagon fleet, or to grow traffic volume with less-than-proportionate wagon fleet growth. Either way, there is a saving in wagon fleet investment. This means that COALlink can accommodate static traffic volume without replacing wagons written off in derailments, or accommodate growing traffic at less cost than investing in more-of-the-same rolling stock.

3.5.3. Reduce derailment damage—14%

Multivariate statistical analysis of derailments revealed that four archetypes accounted for 80% of the cases (Van der Meulen, 2001b). In order of increasing severity, the archetypes are:

Empty trains that derailed on up grades, at relatively high speed, following rapid deceleration.

Loaded trains that derailed on up grades, at low speed, following coupler failure.

Loaded trains that derailed on down grade inflections, at relatively high speed, following axle bearing failure.

Loaded trains that derailed on down grade inflections, at moderate speed, following wheel failure.

Distributed power addresses loaded trains that derail on up grades by reducing coupler forces below the threshold that risks failure. ECP braking addresses the other three archetypes, first through applying wagon brakes simultaneously throughout a train, with uniform pressure at each brake cylinder, and second through graduated release encouraging release of brakes when passing grade inflections. Eliminating such derailments avoids expenditure on repairing infrastructure damage, and making good rolling stock losses. This item does not include loss of lading, which is carried at owner's risk.

3.5.4. Reduce locomotive fleet requirements—14%

This item also relates to faster turnaround. The locomotives turn around faster, for the same reasons as the wagons, and hence fewer locomotives are required for a given level of traffic. The value of the benefit is however different: Because of the diversity of locomotive types, locomotives and wagons operate on different turnaround cycles.

3.5.5. Reduce rolling stock maintenance—10%

Integrated ECP braking eliminates wheelset damage due to uneven distribution of braking thermal load. The wagon-level intelligence and intra-train communication that comes with ECP braking is expected to eliminate the remaining risk in respect of overheated wheels, namely inadvertently applied handbrakes, through provision of force detectors after the application points of brake cylinder and hand brake force in the brake rigging.

Distributed power reduces coupler forces, so that drawgear life is not shortened, and maintenance costs are correspondingly reduced.

3.5.6. Salvage air brake equipment—9%

The business case includes the estimated value of selling service portions, which are released when all-electric ECP braking is implemented, into the second hand market. Spoornet may be able to realize a higher value if it redeploys them to convert vacuum brakes to air brakes, in which case they could be worth the new valve that would otherwise be needed.

3.5.7. Reduce energy cost—6%

Distributing a portion of the total tractive effort to the rear of a train minimizes the amount by which the lateral component of stringlining forces off-track wheelsets, and so reduces energy consumption. Consequently, a distributed power train balances at a slightly higher speed than a head-end power train under the same conditions, which also contributes to turnaround time reduction (this is included under the headings *Reduce wagon fleet requirements* and *Reduce locomotive fleet requirements*).

The graduated release feature of ECP braking eliminates occurrences of train drivers powering against train brakes, or allowing speed to rise unduly against a train brake application, in situations where direct release air brakes do not allow sufficient time to recharge if a release were to be made. Note that such undesirable train handling, that wastefully or improperly dissipates energy, occurs at the same down grade inflections that account for the two most severe derailment archetypes: Thoughtless energy dissipation is therefore not only a problem per se, but one can often follow its flow to a consequential problem.

3.5.8. Reduce train delays—6%

This item reflects the benefits of integrated ECP braking plus DP in rendering service delivery more reliable. It relates to the one above for *Reduce derailment damage*, and accounts for avoiding loss of capacity due to disruption of the service by derailments and train partings. It also includes elimination of undesired emergency brake applications and pneumatic-brake-related train stoppages.

3.5.9. Reduce track maintenance—2%

Placing all locomotives at the head end of a heavy train may disturb the track structure, by straining it longitudinally under high tractive effort, which in turn deranges clips, pads, ties and ballast. Placing locomotives in two, distributed, consists reduces the concentration of tractive effort to below a threshold at which it contributes unduly to track maintenance.

4. THE OREX BUSINESS CASE

4.1. Scope

The insights gained from the COALlink pilot train provided a starting point from which to approach a business case for integrated ECP braking plus distributed power on the Orex operation. The following additional considerations apply:

First, the nature of the benefits included in the COALlink business case suggested that a further pilot scheme on Orex would not deliver significant new insight. The outcome is therefore not expected to differ materially from that of the COALlink business case, although the distribution of the benefits could well differ.

Second, the Orex operation comprises single track, whereas the COALlink operation comprises essentially double track. This distinction renders the former sensitive to turnaround time issues and -benefits. Thus, the largest contribution is expected from faster turnaround, and hence reducing rolling stock requirements. Improved train handling, higher speeds on down grades, and less time spent on brake testing before departure, will make these benefits possible.

Third, the Orex operation is comparatively simple, without complex feeder services. Rather than using transition devices or -vehicles, it will probably be cost effective to simply convert all rolling stock to integrated ECP braking plus DP.

4.2. Essential content

4.2.1. Strategic development

Strategic development could prove to be a major determinant. At envisaged traffic levels, there is no need to contemplate doubling the line, although intermediate passing loops have been provided, and options for traffic growth are thus in principle confined to higher axle load, longer trains, and faster turnaround.

Faster turnaround offers the largest quantifiable benefit, by reducing time spent on brake tests, of the order of 90-120 minutes per terminal, in a total cycle of some 60 hours. Furthermore, the running time benefits discussed in Paragraph 4.3 would also apply.

4.2.2. Current constraints

Although the business case for upgrading to the present 30 tonnes/axle did not include peripheral issues, some have emerged. These include constraints at both loading- and unloading terminals, where the additional volume of iron ore per unit time resulted in longer turnaround time, and dipped rail joints. It is therefore improbable that axle load will be further increased.

If train length, and hence tonnage, were to be increased beyond present parameters, continued use of head-end power only would push coupler forces beyond prudent limits, thereby threatening system reliability. Distributed power can increase aggregate tractive effort per train, while decreasing the force applied at any particular coupler.

4.2.3. Alternative solutions

One possible solution would be to use radio-based distributed power only. There are however three detracting considerations. First, it would address high coupler force issues, but offer no benefit in respect of thermal loading on wagon wheels, simultaneous and uniform response on all wagons, and terminal brake testing time. Second, the time taken to link distributed locomotive consists may prove to be a negative benefit. Third, implementation of a mature technology might thwart later implementation of a new technology with extensive development potential, through requiring two tranches of investment to achieve benefits that are more ably provided by integrated ECP braking plus DP.

Another possible solution would be to equip all rolling stock with an intra-train communication cable, and use it initially for distributed power only. This would return some immediate benefits, without thwarting an upgrade path to full exploitation of new technology at a later stage.

4.3. A practical simulation

4.3.1. Methodology

Instead of a pilot scheme, the author undertook a real-train simulation, to establish a basis for a business case. The responsiveness of ECP braking was simulated, for test purposes only, by adding sufficient extra locomotives to the regular train to use their dynamic brakes to substitute for energy dissipated by wagon wheels, at any speed. It proved possible to handle the train with dynamic braking only (other than for stopping), thus simulating the instantaneous response of ECP braking. The test train drivers had been given an opportunity to handle the COALlink pilot train, to encourage them to drive a conventional air braked train as if it were a graduated release ECP braked train. That is, in situations where they needed to graduate the brake off, they could simply reduce dynamic braking. The train consisted of the regular 216 wagons, loaded to 120 tonnes gross, plus two instrumentation wagons, for a trailing load of 26000 tonnes. The locomotives were placed in three consists: the regular two Class 9E electric locomotives leading, but the regular five Class 34 diesel locomotives at the rear, to simulate distributed power both in traction and dynamic braking; in addition Class 9E locomotives, two in front and five in the middle, provided dynamic braking only. As set up at the time of the simulation, Class 9E locomotives provided 3600kW in traction and dynamic braking, and Class 34 locomotives provided 1500kW in traction and dynamic braking, all at rail. The regular tractive and dynamic braking power was 14700kW; a supplementary dynamic braking capacity of 25200kW was available to simulate the instantaneous graduated release response of ECP braking. Permissible speed on long down grades was raised from 50km/h to 60km/h, to simulate the benefit of uniform thermal loading on wagon wheels characteristic of ECP braking.

4.3.2. Findings

The simulation did not fully meet expectations, for two reasons. First, despite the prior exposure, plus coaching en route, the train drivers had difficulty in shifting their train-handling paradigm from air brake to ECP brake. No doubt, one could overcome that obstacle with sufficient practice runs. Second, the simulation was predicated on a reduction in running time, and train drivers are reluctant to deliver slick performance during a recorded test run. In the event, the simulation delivered a running time reduction of 40 minutes, from 17 hours 30 minutes to 16 hours 50 minutes. Subjectively, the author expects a one-hour reduction under routine conditions.

4.4. Prognosis

The Orex operation is growing. Although it can handle the current contractually committed 29 million tonnes per year with existing assets, when demand increases beyond that, further investment will be required. Integrated ECP braking plus DP is attractive, because it offers faster turnaround, through shorter running times and quicker terminal tests. Of the growth options available, integrated ECP braking plus DP offers the highest profitability index. This situation, in combination with the positive outcome of the COALlink business case, forms a key element of the conclusions that follow.

5. CONCLUSIONS AND WAY FORWARD

5.1. Compelling competencies of integrated ECP braking plus distributed power

At high level, the business cases introduced here may appear similar, as indeed they are in many respects, but reflection on their differences illustrates the broad-based competencies offered by integrated ECP braking plus DP. The technology can mitigate systemic constraints or problems in widely divergent operations, through opening up an alternative to either pushing engineering constraints or incremental capacity investment. The author argues that this alternative approach will determine where the industry takes this technology in future.

5.2. Relations to traditional constraints

Note that turnaround time featured prominently in both business cases, although their relative importance did differ.

Note also that integrated ECP braking plus DP either relaxed engineering constraints, or permitted higher loading within existing engineering constraints. In particular, the more uniform temperature distribution from wagon to wagon literally takes the heat off brake system design, while DP renders a train unbreakable with respect to longitudinal forces.

Together, these two factors give impetus to a new approach, in which a railway can increase capacity without either incremental investment or higher stress, by in the first instance exploiting quicker turnaround.

5.3. A new growth dimension

Arguably the strongest case for integrated ECP braking plus DP, as a package, is thus that it adds a fifth dimension to the traditional quartet of approaches to increasing throughput capacity, namely increasing axle load, increasing train length, strengthening wagon- and locomotive fleets, and adding more infrastructure. It grows capacity without pushing the envelope of engineering constraints, which tends to be on the limit already in heavy haul railways. On the contrary, while it accelerates turnaround time, by reducing running time and terminal time sufficiently to justify itself, it contributes a package of benefits that enhances the humanity, reliability, and robustness of a heavy haul operation. It is a worthwhile technology indeed!

5.4. A fence around heavy haul?

The author has previously noted that changing interoperability standards is notoriously difficult and costly, and concluded that high investment requirements for new train technology might trigger a bifurcation of destiny between heavy haul and heavy intermodal traffic on the one hand, and general freight traffic on the other hand (Van der Meulen, 2001c). The business cases introduced above seem to reinforce that position. Perhaps the greatest challenge in the project reported here has been to define the interoperability interface between ECP braked trains and the rest. The envisaged investment will create a high barrier to entry, and the resultant benefits will be one-sided. It is improbable that general freight traffic will support such investment, and without it, its competitiveness could wane.

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